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STORAGE STABILITY OF CIVIL DEFENSE SHELTER RATIONS

(ANNUAL REPORT)

by

SAM R. CECIL

UNIVERSITY OF GEORGIA
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Stanford Research Institute
Menlo Park, California 94025

FOREWORD

This is the seventh annual report in a study of the stability of representative types of Civil Defense shelter foods and their containers when stored for extended periods. The purpose of the study was to maintain controlled storage conditions covering the range of conditions likely to exist in warehouses and shelters in which, beginning in 1962, large quantities of food were stored under the Civil Defense Shelter Program. These included types of food not previously procured, representing new formulations, processes and containers on which little or no long-term storage information was available.

The first five reports were issued by U. S. Army Natick Laboratories, Natick, Massachusetts 01760, under Contract DA19-129-QM-2050(N) with University of Georgia. The sixth and seventh (present) reports were issued by University of Georgia under the current subcontract, for which the Project Officer is Dr. James F. Halsey, Civil Defense Technical Office, Stanford Research Institute.

It is anticipated that the study will be concluded in 1970, as reserve stocks of rations are sufficient for only one more complete storage evaluation.

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Sam R. Cecil
Food Scientist
Georgia Station,
College of Agriculture,
University of Georgia

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APPROVED:

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ABSTRACT

Results are reported on the stability of 6 lots of fallout shelter cereal rations and 3 lots of carbohydrate supplement stored 6 and 5 years, respectively, at 70°F/80% r.h., 70°/57%, 40°/57%, and 0°/ambient r.h. Cereal rations include 2 lots each of survival crackers, biscuits, and bulgur wheat wafers. Samples of 7 items (2 crackers and 5 biscuits) held 2-3 years at 70°/57% after withdrawal from warehouse stocks were also examined, but samples of supplement and cereal rations held 5-6 years at 100°/80% and 100°/57% were omitted as unsuitable for further storage. Data include (1) bursting strength, moisture content, and general condition of V3c fiberboard cases; (2) residual oxygen, leaking and condition of seams, corrosion, and coating defects of 2½-gallon and 5-gallon metal cans; (3) breakage of package seals, seams or materials, and of product units; (4) fracture strength and rancidity values of cereal items, (5) pH and sugar contents of supplement items, and (6) moisture content, color, sensory quality, and hedonic ratings of all items.

STORAGE STABILITY OF CIVIL DEFENSE SHELTER RATIONS
(ANNUAL REPORT)

Introduction

A storage study was conducted over a six-year period to determine the stability of representative types of Civil Defense shelter rations. At the beginning of this period, 10 cereal items were deposited in storage over an interval of four months, and 3 carbohydrate supplements were stored about a year later. Determinations were also made of the stability of packaging materials in which the rations were stored.

In September 1965 samples of a biscuit item in 2½-gallon cans were removed from a CDM warehouse, and in February 1967 two cracker items and four biscuit items in 2½-gallon cans were drawn as part of a limited-scale warehouse sampling survey. Extra cans of these seven items were placed in controlled storage at 70°F/57% r.h. as received, and results of the original sampling and current values from controlled storage are included in this report.

Manufacturing and general storage data for all controlled-storage and warehouse items are given in Table 1. Warehouses from which the seven extra items were drawn were as follows:

Code	Warehouse
WB1	GSA/CDM NIRC Depot, Seneca, Illinois
WC5	Naval Supply Center, Oakland, California
WC6	Naval Ammunition Depot, Crane, Indiana
WB8	Atlanta Army Depot, Forest Park, Georgia
WB9	GSA/CDM Depot, Rossford, Ohio
WB10	Atlanta Army Depot, Forest Park, Georgia
WB11	GSA/CDM Sharonville Depot, Cincinnati, Ohio

The storage period covered in the report was November 1967-February 1969. Average conditions, and standard deviations above and below averages, were:

Code °F/%r.h.	Temperature °F	Relative Humidity percent
70/80	70.0, +1.1, -0.7	80.5, +1.9, -0.9
70/57	70.0, +0.4, -0.4	57.9, +1.5, -1.1
40/57	40.0, +0.6, -0.4	57.5, +2.4, -1.3
0/amb	0.2, +2.8, -0.8	ambient (high)

The somewhat large deviations at 40/57 and 0/amb conditions resulted from defective functioning of control equipment and off-time required for replacements. As recordings were made in room air spaces adjacent to the stacks of rations, deviations within cases and cans probably averaged less than those listed.

It is noted that the 100°F/80% r.h. and 100°F/57% r.h. conditions, reported through the fifth year of storage in 1968, are omitted here. As a preliminary check to assist in deciding how to proceed with the 1968-69 examinations of rations, 33 single-can samples were partially evaluated (oxygen, rancidity values, flavor scores on cereal items, color and flavor scores on supplements) in August 1968, and subsamples were sent to Office of Civil Defense for sensory examination. These extra cans were as follows:

Condition	CD Number											
°F/% r.h.	crackers				biscuits			wafers		supplements		
100/80		3				4						
100/57	1	3	5	8	2	4	7	9	10	11	12	14
70/57	1			8	2		7	9	10	11	12	14
40/57	1			8	2		7	9	10	11	12	14
0/amb												14

Results for the 70°, 40° and 0°F samples were about the same as those which will be tabulated in the current report. Results for samples from 100°F were as follows:

	panel scores		residual	rancidity values	
	color	flavor	oxygen	peroxides	free fatty acids
crackers	-	3.0 ± .8	7.0 ± 3.9	15.3 ± 10.3	.61 ± .22
biscuits	-	2.5 ± .7	10.6 ± 7.6	13.5 ± 6.4	1.01 ± .24
wafers	-	3.8 ± .6	3.2 ± 1.4	4.2 ± 1.9	.96 ± .04
supplements	5.1 ± .5	4.7 ± .6	-	-	-

Based on these results, it was decided to omit 100°F storage from further sampling, and to conserve remaining rations at 70°F and below for as full-scale sampling as possible after the seventh year (six for supplements) of storage. Items remaining for examination during the current year thus became those listed in Table 1, while these and CD3 and 4, CD5 at 70°/57% and 0°/amb, and a warehouse wafer sample at 70°/57% are being carried into the additional year.

For data contained in this report, samples consisted of two cans and one case from each storage condition, with the exception of the warehouse items stored only at 70°/57%. Basic procedures and sample replicates for the various observations and determinations included in the examinations are given with the results and data reported below. Statistical treatment of data employed standard procedures for analysis of variance, multiple range testing for significance, and calculation of simple correlation coefficients.

Methods and Results

1. Fiberboard (V3c) Cases

Entire cases were used for all "CD" items except cracker CD1. This item and the seven warehouse samples, in 2½-gallon cans, were examined by removing the center 1/3 of cases which had been sampled once and reclosed at an earlier period.

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TABLE 1

FALLOUT SHELTER RATIONS EXAMINED 1968-69

Item code[a]	Units lb	Pounds can	Contract number	Lot number	Manufacture date		Months Since Manufacture warehouse, shipping	controlled storage
crackers:								
CD1	62	7.3	2692-62	F5	Sept	1962	2	73
CD8	91	12.7	2691-62	29,30	Nov	1962	3	70
WC5	128	7.2	2689-62	-	Aug	1962	55	21
WC6	62	7.4	2692-62	H1	Sept	1962	53	22
biscuits:								
CD2	92	12.7	2686-62	0221,2,5	Oct	1962	1	73
CD7	93	14.6	2687-62	6,7	18 Oct	1962	2	72
WB1	66	6.7	1957-62	A19	April	1962	42	38
WB8	63	6.2	30-541	02	Feb	1962	60	22
WB9	129	6.1	1954-62	-	March	1962	59	22
WB10	66	6.0	1955-62	11	March	1962	59	22
WB11	66	6.2	1957-62	23	March	1962	60	21
wafers:								
CD9	22.9	33.0	2254-62	6	Oct	1962	3	71
CD10	23.3	32.3	2254-62	10(HA)	Oct	1962	3	71
supplements:								
CD11	120	34.3	24018-63	29	Aug	1963	7	59
CD12	89	35.8	24016-63	25	June	1963	9	59
CD14	106	33.9	24013-63	0916	Sept	1963	6	59

[a]"CD" items are those of the controlled storage study. "W" items were samples taken from warehouses in 6-can cases, with 2 cans used as sample and 4 cans stored at 70°F/57% r.h. for further examination.

Ten 4-inch squares were cut from available locations on side and end panels of each case and placed in sealed containers before removal from the storage room. Containers were then removed to a 73°F condition, allowed to equalize at this temperature, and bursting strength determined as rapidly as possible after opening the container, using a manually operated Mullen-type tester.

1. Bursting Strength (Table 2)

Cases of cereal items averaged practically no change in bursting strength during the sixth year at 70°F, with average decrease of about 30 psig at lower temperatures. Supplement cases decreased about 10 psig at 70° and 30 psig at 40°F during the fifth year, with essentially no change at 0°F. Mean deviation from initial values, as given in Table 2, were as follows for the last two years of storage:

Condition	cereal item cases		supplement cases	
°F/% r.h.	5 years	6 years	4 years	5 years
100/80	-178	-	-87	-
100/57	-148	-	-85	-
70/80	-47	-47	-8	-17
70/57	-7	-8	-1	-14
40/57	67	40	50	21
0/amb	54	22	34	36

The above changes in bursting strength suggest a general, though variable, pattern with storage temperature. The decreases at 100°F took place largely within the first four years, while values at 70°F were fluctuating but not generally decreasing, and those at 40° and 0° exhibited moderate increases. After about the fourth and fifth years, bursting strength at 70° and lower temperatures, respectively, apparently began to decrease slightly, although both of the lower temperatures still averaged above initial at five and six years.

It can be seen from Table 2 that nearly all of the cases remain near or above the specified 400 psig bursting strength, and that the warehouse sample cases have changed very little in controlled storage at 70°/57%. Although correlations of bursting strength with moisture content were quite variable, deviations from initial values at 100° and 70°F suggest somewhat greater reductions in bursting strength at the 80% r.h. conditions.

2. Moisture Content (Table 3)

Samples for moisture determinations were obtained at the same time and in the same manner as those for bursting strength. Moisture was calculated from weight losses of 5 grams of chopped fiberboard after heating 5 hours at 100°C under a 29-inch vacuum.

Moisture values listed in Table 3 averaged 0.3 ± .2% lower than for the previous year at 70°/80%, 0.0 ± .3% in comparisons with previous values at

TABLE 2

BURSTING STRENGTH OF V3c FIBERBOARD
(pounds per square inch)

A. Cereal Item Cases Stored Six Years

Storage	Items in Controlled Storage							
°F/% r.h.	CD1	CD8	CD2	CD7	CD9	CD10	std.dev. 10 reps	Mean
Initial	485	535	451	483	498	463	33	486
70/80	411	528	486	477	373	359	27	439
70/57	440	557	480	492	470	426	31	477
40/57	454	595	510	559	525	510	40	526
0/amb	471	558	509	538	466	505	56	508
std.dev. 10 reps	48	51	40	37	42	33	-	42
sign.dif., 5%	44	46	29	34	38	30	40[a]	16
Mean	444	559	496	516	459	450	19[b]	487

	Warehouse Samples Transferred to Controlled Storage								
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dev. 10 reps	sign.dif. 5%	Mean
sample[c]	480	494	479	510	388	383	430	33	34	452
70/57	499	502	463	447	395	400	429	29	32	448

B. Carbohydrate Supplement Cases Stored Five Years

	Items in Controlled Storage				
	CD11	CD12	CD14	std.dev. 10 reps	Mean
Initial	548	365	514	35	476
70/80	524	380	404	33	436
70/57	505	353	448	36	435
40/57	493	421	479	23	464
0/amb	520	472	476	58	489
std.dev. 10 reps	56	37	26		42
sign.dif., 5%	NS	34	24	37[a]	22
Mean	510	406	452	19[b]	456

[a] Significant difference for items in rooms.
[b] Significant difference for item means.
[c] Sample values when removed from CDM warehouses, before transfer to controlled storage.

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70°/57% and 40°/57%, and 1.0 ± .8% lower at 0°/amb. Levels varied with temperature and relative humidity, averaging 10.9 ± .2% at 70°/80% and 13.2 ± .7% at 0°/amb (high r.h.), but 7.6 ± .2% at 70° and 8.9 ± .2% at 40° in the 57% r.h. rooms. There was apparently no serious damage from the higher moisture levels; only moderate increases in staining of cases and slight increases in bulging in stacks were observed. As mentioned above, there was some suggestion of reduced bursting strength in fiberboard having the higher moisture contents, but this was generally too variable for statistical significance.

3. General Condition of Cases

All the cases showed more or less evidence of staining and slight "wear" from handling in storage rooms which were also in use for other commodities. The resulting "slightly used" appearance, however, had little influence on their function as containers for the ration cans. Certain of the minor imperfections observed during the most recent examinations are given below; ratings for extent, where given, are on a 9-point scale.

Loose Seals. There was no apparent increase in setting or cracking of of adhesive on flap seals during the last year, nor have any seals "come unglued". Loose flap edges, from inadequate spreading of adhesive at time of closing, were noted in approximately half of the cases of CD7, 10 and 11 (mean rating 0.5) as before, but no damage resulted except slight fraying of the loose corners of the flaps. Staples from 70°/80% did not appear noticably rustier than after four to five years, and none of the staples were pulled out or broken.

Delamination. The only signs of delamination of the fiberboard were some slight separations at the cut edges of the 11 warehouse and CD1 cases which had been previously sampled and resealed with tape. Of the more than 600 cases examined during the entire period of the study, the only delaminations not due to obvious physical damage were observed as one fairly small area (a few square inches) midpanel in each of one case of CD6 from 70°/80% at two years, one of CD1 from the same condition at three years, and one of CD8 from 100°/80% at five years. Defect ratings for these averaged 2.9 ± 1.1. It seems probable that these areas were the result of fabrication defects or damage not otherwise noted, as none of the other cases of these or other items have shown any indication of being delaminated by moisture absorption in the high humidity rooms.

Mold. Only two slight spots of mold (rating 1.0)were observed during the sixth-year examinations, one in the inside bottom of warehouse sample WB8 from 70°/57% and a similar spot in CD10 from 70°/80%. No molding of outside surfaces of cases was found. The fact that most of the molding observed during the study was noted during the first four years (small areas inside and outside of about 20% of the cases stored at 70°/80% and 5% of cases stored at 100°/80% and 70°/57%) would seem to indicate a general lack of contamination during the later years, after moving into the new storage rooms.

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TABLE 3

MOISTURE CONTENT OF V3c FIBERBOARD
(percent)

A. Cereal Item Cases Stored Six Years

Storage °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. 2 reps	Mean
Initial	7.3	7.4	6.7	7.5	7.5	7.5	.03	7.32
70/80	11.1	11.1	10.9	11.2	10.7	11.0	.03	11.00
70/57	7.6	7.4	7.5	7.6	7.5	7.6	.04	7.54
40/57	9.0	8.7	8.9	9.0	8.8	9.0	.05	8.90
0/amb	13.3	12.3	13.4	12.8	12.3	12.9	.05	12.82
std.dif., 2 reps	.03	.02	.07	.05	.04	.04	-	.04
sign.dif., 5%	.05	.03	.13	.10	.07	.08	.06[a]	.03
Mean	10.24	9.85	10.20	10.14	9.83	10.11	.03[b]	10.06

	Warehouse Samples Transferred to Controlled Storage									
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. 2 reps	sign.dif. 5%	Mean
sample	8.0	7.5	7.9	8.0	8.0	7.8	7.3	.06	.12	7.78
70/57	7.6	7.3	7.5	7.6	7.6	7.5	7.1	.04	.07	7.47

B. Carbohydrate Supplement Cases Stored Five Years

	Items in Controlled Storage				
	CD11	CD12	CD14	std.dif. 2 reps	Mean
Initial	7.9	7.6	7.8	.05	7.78
70/80	11.0	10.7	10.7	.05	10.77
70/57	8.0	7.6	7.9	.02	7.85
40/57	8.9	9.0	8.9	.08	8.96
0/amb	14.1	14.1	13.8	.08	14.01
std.dif. 2 reps	.06	.05	.08	-	.06
sign.dif., 5%	.10	.09	.16	.10[a]	.06
Mean	10.50	10.36	10.33	.05[b]	10.40

[a] Significant difference for items in rooms.
[b] Significant difference for item means.

Sweating of Cases and Cans. In general, sweating of cases and cans averaged about the same as previous high ratings (change +0.1 + .5) at 70° and 0°F, with an average increase of 0.4 + .7 at 40°/57%. By location, average ratings, changes from previous high ratings, and deviations among the cases from each storage room were as follows:

Condition	outside of case		inside of case		staining of cans	
°F/% r.h.	rating	change	rating	change	rating	change
70/80	1.1 + .7	.0 + .4	1.3 + .5	.0 + .6	1.4 + .6	-.3 + .3
70/57	.8 + .6	.0 + .5	1.0 + .5	.3 + .5	1.0 + .6	.1 + .5
40/57	1.0 + .8	.4 + .7	1.3 + .9	.5 + .8	1.0 + .6	.2 + .4
0/amb	.8 + .4	.2 + .4	.8 + .4	.2 + .3	.9 + .'	.1 + .3
warehouse	.9 + .4	.5 + .3	.6 + .3	.2 + .4	.2 + .1	.0 + .1

As seen, the staining of outside surfaces of warehouse sample cases was about the same as that of the long-term storage cases, but more than half of the warehouse case sweating has occurred since they were placed in the 70°/57% room. Staining of the inside surfaces of cases and outside of cans were still considerably less in the warehouse samples than in the "CD" items. There are apparently two reasons for these differences: (1) cases in the storage rooms, under continuous control and in active use, are more exposed to fluctuations which can result in sweating and staining than are those in the more "inactive" conditions of the warehouses, and (2) all of the warehouse cans were 2½-gallon type, which have proven much less subject to staining and corrosion than the 5-gallon cans in which five of the six CD items were packed.

Although somewhat unsightly in a few instances, none of the staining of cases or cans was severe enough to interfere with continued utility in storage.

Collapse. As noted in previous reports, cases are stacked only three high in the controlled-storage rooms, so do not furnish any real test of collapse. The ratings used are for bulging of sides and ends until tops and bottoms of cases rest firmly on the cans, which have shown no indication of collapsing except in a few instances of partial crushing during shipment. Mean ratings for bulging for the current examinations were 1.0 + .3 at 70°/80%, an increase of .3 + .5 over previous ratings, and 0.5 + .3 at other conditions, a decrease of .2 + .5. The lighter cracker and biscuit cases, averaging 35 lbs, rated 0.4 + .4; heavier wafer and supplement cases, averaging 75 lbs, rated 0.3 + .3. The only difference between warehouse cases and the CD cracker and biscuit cases was that three of the warehouse cases averaged 1.2 + .6 lower than when originally sampled. These had damaged ends when received, and these ends were used, leaving the undamaged 2/3 of each case for continued storage and current examination.

4. Condition of Case Markings

There has been very little change in condition of case markings since the rations were received for storage. Fading of print, which averaged

0.3 ± .2 after 5 years at 100°F, averaged 0.2 ± .1 for all cases examined
from lower temperatures at 6 years--warehouse cases at 70°/57% averaged
0.3 ± .2. In all instances, changes from previous values averaged
0.0 ± .3, indicating no apparent storage or time effect. Blurring of print
has increased somewhat with handling of the cases in periodic sampling,
high values being reached at various periods between 2 and 5 years, with
average high at 4 years. Current ratings for blurring average 0.4 ± .3,
down 0.2 ± .3 from previous highs; warehouse cases averaged 0.5 ± .4, the
same ± 0.2 as when received. Thus there is still no indication that case
markings may become illegible unless painted over or scrubbed off.

II. Metal Cans

Cans of cracker CD1 and the seven warehouse samples were 2½-gallon type,
containing 5.8 to 7.2 lbs. of crackers or biscuits. All others were 5-
gallon type, containing 12.8 to 14.0 lbs of crackers or biscuits, 32 to 33
lbs of bulgur wafers, or 34 to 36 lbs of carbohydrate supplement. All
samples consisted of two cans each.

1. Residual Oxygen in Cans (Table 4)

Oxygen remaining in the can space was determined as the lowest reading
obtained while passing gases from the can through a direct-reading oxygen
analyzer adjusted to a fresh air reading of 20.9% by volume. Determinations
were made only for cereal items.

As seen in Table 4, the oxygen pattern was quite variable. Among the
62 cans of cereal rations were 7 definite leakers (6 of them in the 2½-
gallon cans), all having higher oxygen values than at some previous examination.
Of 18 questionable leakers, however, only 10 were higher than previously,
and 13 of the 37 non-leakers were also higher (10 of these were wafers).
Thus the possibility of undetected slight leaks was again suggested. A
summary of mean values among the 53 non-leakers and 42 leakers (including
single-can samples of August 1968), as compared to previous low values,
is as follows:

Condition °F/% r.h.	previous low values months	% oxygen	values at six years nonleakers	leakers
100/80	43 ± 19	5.0 ± 2.1	5.3	19.6
100/57	54 ± 12	2.9 ± 1.3	2.1 ± 1.3	12.2 ± 5.0
70/80	56 ± 6	8.0 ± 5.2	7.3 ± 5.2	13.9 ± 2.0
70/57	53 ± 14	8.7 ± 5.1	8.2 ± 3.5	16.4 ± 2.8
40/57	53 ± 5	12.5 ± 5.6	8.5 ± 5.6	16.4 ± 2.5
0/amb	46 ± 7	15.6 ± 3.1	15.8 ± 1.6	20.2 ± 0.6

The large deviations resulted mostly from differences in oxygen levels
among the three types of products. Reference to Table 4 will show that
oxygen was low in wafers except at 0°F, higher in crackers, and highest
in biscuits. For example, at 70°F wafers average around 2%, crackers 7-10%,
biscuits 12-15%.

Wafer cans contain considerably greater weight of product per unit
volume, although probably not a greater relative surface area, but crackers
and biscuits are quite similar in both weight and surface area. Thus there
seems to be a differential absorption pattern among the three products.
Apparently crackers and biscuits, and at least some of the wafers, retain
sufficient oxygen to support the increasing oxidation reactions observed
during the current period in both the items included in the storage study
and in samples from representative warehouses examined by U.S. Army
Natick Laboratories.

2. Leaking Cans (Table 5)

Leaks were detected as streams of bubbles when cans at 73°F were
immersed 2 minutes in water at 103-105°F; questionable leakers were those
cans emitting only a few bubbles, but whose oxygen, moisture or rancidi y
values indicated that leaking had probably occurred.

The percentages of leakers and questionable leakers given in Table 5
include the 33 extra cans opened in August 1968 for partial examination,
and all cans examined as warehouse or shelter samples.

The periodic comparisons of leakers indicated that leaking is increasing
with storage in most of the cans of rations, but not in all. Items CD4
(2½-gal can) is the extreme--54% leakers and 21% questionable the first 3
years and 100% leakers thereafter. Item CD11 had 17% leakers and questionable
leakers at 0-3 years, 26% at 4-5 years, with about equal numbers in each
leak category. Items CD3 and 6 averaged ca 19% leakers over 5 years with
little evidence of increase, but questionable leakers were up from 4% at 3
years to 21% during the fourth and fifth. CD1 was similar, having 7% leakers
over 5 years but increasing in questionable leakers from 6% to 21% between
3 and 5 years; this item, however, had 45% leakers and 55% questionable at
6 years.

Warehouse samples were well up in the listings, averaging 14% leakers
and 10% questionable during the fourth year, with 28% leakers and 30%
questionable in the 2½-gallon cans examined during the sixth year.

Three items, CD7, 8 and 12, apparently had seams which were adequate
for 3-4 years, with leaks beyond this period. CD12 had about 3% total through
3 years, then 21.7% each of leakers and questionable at 4-5 years. CD7 and
8 had no leakers except a few damaged cans for 5 years, then 14% leakers
at 6 years; questionable leakers averaged 2% at 0-3 years, 8% at 4-5 years,
and 18% at 6 years.

In contrast to the above, five items have shown little or no increase
of leaking with storage. CD5 and 13 averaged 8% leakers and 5% questionable
during the first 3 years, 6% leakers and none questionable at 4-5 years.
CD2, 9 and 10 have had practically no leakers at any examination, with less
than 2% questionable at 0-3 years, 10% questionable at 4-5 years, but only
3% questionable (one can) at 6 years. Thus it seems apparent that leaks in
these items resulted from incidental damage or faulty seaming, with no
definite storage effect.

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TABLE 4

RESIDUAL OXYGEN IN CANS OF CEREAL ITEMS STORED SIX YEARS
(percent by volume)

Storage °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std. dif. cans	Mean
Initial	19.3	20.4	20.1	20.4	16.6	17.0	.48	18.94
70/80	8.9	9.9	12.4	14.4	1.2	1.2	1.46[b]	8.00
70/57	8.9	8.4	12.4	14.4	3.9	2.4	.50	8.40
40/57	13.9	11.9	15.9	18.9[a]	2.4	3.9	.50	11.15
0/amb	13.9	19.4[a]	18.9[c]	20.7[b]	15.9	15.1	2.80[b]	17.32
std.dif.,cans	3.60[b]	.62	.83	.87[b]	.44	.87	-	1.62[b]
sign.dif., 5%	5.60	1.21	1.63	1.71	.86	1.71	1.67[c]	.97
Mean	11.40[a]	12.40	14.90	17.10	5.85	5.65	.84[d]	11.22

	Warehouse Samples Transferred to Controlled Storage									
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
sample	11.4	7.9	17.8	13.7	18.6	20.9[b]	14.9	1.26[b]	2.10	15.93
70/57	9.9	6.9	15.9[a]	14.7[a]	16.9[b]	19.9[b]	13.9[a]	1.94[b]	3.25	14.01

[a] Questionable leaker(s).
[b] Leaker(s). Definite leakers, omitted except in WB10 (both cans) and in standard difference values where indicated, averaged 3.6 ± 1.5% higher than nonleakers and questionable leakers.
[c] Significant difference for items in rooms.
[d] Significant difference for item means.

<u>Can Seams</u>. On 4 April 1969, side and top seams of cans CD1 and CD4
(2½-gallon) and side, top and circular lid seams of cans CD2, CD11 and CD12
(5-gallon) were filed, spread and examined under magnification. The single
side seams of the 2½-gallon cans proved to be double-lapped seams soldered
inside against the can body, with about ½ inch of outside soldering at the
top (possibly where solder had run through at the cut top edge of the can).
The two (diagonal) side seams of the 5-gallon cans were similarly lapped,
but soldered into the seam from the outside. Top (and bottom) seams of the
larger cans are also double-lapped soldered seams, the solder having been
applied to seal the laps against the outside surface of the can. There has
been practically no leaking from any of the soldered seams of 2½-gallon or
5-gallon cans.

The top circular lid seams of 5-gallon and top (and bottom) rectangular
seams of 2½-gallon cans were all (of the five items examined) double-
lapped compound-sealed seams; i.e., standard double seams. The compound of
the circular (5-gallon) seams was located between the outside of the body
flange and the standing part of the rolled lid overlap, thus providing
a relatively thick layer of sealant. The compound of CD2 was apparently
quite flexible and adhesive, while that of CD12 was slightly less so, and
the compound of CD11 seemed somewhat set and non-flexible. CD11 seams were
also slightly more tightly and flatly rolled, particularly as compared
to those of CD2.

The double seams of the lids of CD1 (2½-gallon) appeared to be good,
but the compound was spread somewhat thin, extending down into the bottom
of the lid roll, and though flexible, had lost its "tackiness". The seams
of CD4 (100% leakers after the third year) were much shorter and tighter,
apparently from a short base plate and tight seaming rolls, so that the
body flange had failed to reach into the bottom turn of the lid roll in
some places. The compound was also thin, non-flexible, and in some sections
almost flaky.

Thus the relative condition of the can seams was well correlated with
the pattern of leaks observed in the various items. From this pattern, it
seems probable that defective double seaming and improper application of
seaming compound (at least for long-term storage) have been the major
causes of leaking cans. These defects can be prevented, as was apparently
done with items CD2, 9 and 10 and could be done even with the side and end
seam overlaps of the 2½-gallon cans (a predominant location of leaks
observed). It should therefore be possible to use these types of cans,
with proper care in seaming, for packing in nitrogen atmospheres to
reduce the oxidation of the rations and prolong shelf life beyond that
currently predicted for the present stocks.

TABLE 5

LEAKING CANS
(as percentage of cans examined)

Items	Definite Leakers				Questionable Leakers				Total Cans[a]
	0-3yr[a]	4-5 yr	6 yr	All[a]	0-3yr[a]	4-5 yr	6 yr	All[a]	
(2½-gal)									
CD1	9.4	0.0	45.5	11.1	6.3	20.8	54.5	15.2	26.3
CD3	10.6	20.8	50.0	14.1	4.5	16.7	0.0	7.6	21.7
CD4	54.5	100.0	100.0	67.4	21.2	0.0	0.0	15.2	82.6
warehouse	-	11.9	28.6	16.1	-	14.3	50.0	23.2	39.3
(5-gal)									
CD2	0.0	0.0	0.0	0.0	3.1	12.5	9.1	6.1	6.1
CD5	9.1	8.3	0.0	8.8	6.1	0.0	0.0	4.4	13.2
CD6	26.6	20.8	-	25.0	3.1	25.0	-	9.1	34.1
CD7	1.6	0.0	18.2	3.0	3.1	4.2	18.2	5.1	8.1
CD8	0.0	0.0	9.1	1.0	1.6	12.5	18.2	6.2	7.2
warehouse	-	16.7	-	16.7	-	22.2	-	22.2	38.9
CD9	1.6	0.0	0.0	1.0	1.6	4.2	0.0	2.0	3.0
CD10	0.0	0.0	0.0	0.0	0.0	12.5	0.0	3.0	3.0
CD11	9.4	13.0	-	10.3	7.8	13.0	-	9.2	19.5
CD12	1.6	21.7	-	6.9	1.6	21.7	-	6.9	13.8
CD13-14	7.9	4.2	-	6.9	3.2	0.0	-	2.3	9.2
Condition °F/% r.h.									
(2½-gal)									
100/80	20.0	33.3	50.0	25.0	23.3	16.7	0.0	20.5	45.5
100/57	20.0	41.7	100.0	31.1	3.3	16.7	0.0	6.7	37.8
70/80	40.0	50.0	50.0	43.2	6.7	0.0	50.0	6.8	50.0
70/57	16.7	18.5[b]	29.4[b]	19.8[b]	20.0	13.0[b]	52.9[b]	21.0[b]	41.6[b]
40/57	30.0	41.7	33.3	33.3	10.0	8.3	66.7	13.3	46.6
0/amb	26.7	33.3	50.0	29.5	3.3	25.0	50.0	11.4	40.9
All	25.0	29.3	41.4	28.0	10.7	13.2	44.8	14.5	42.5
(5-gal)									
100/80	3.0	5.9	-	3.7	3.0	23.5	-	8.2	11.9
100/57	5.0	2.7	16.7	4.9	4.0	10.8	0.0	5.6	10.5
70/80	6.0	0.0	9.0	4.0	1.0	12.5	10.0	4.7	8.7
70/57	8.0	13.1[b]	6.7	9.7[b]	1.0	8.2[b]	0.0	3.4[b]	13.1[b]
40/57	5.0	11.6	0.0	6.3	3.0	9.3	0.0	4.7	10.7
0/amb	3.0	7.3	10.0	7.9	6.0	7.3	40.0	8.6	16.5
All	5.0	7.4	5.6	6.2	3.1	11.3	8.9	5.7	11.9
(all cans)									
Total	10.3	14.3[b]	17.5[b]	11.9[b]	4.9	11.9[b]	21.2[b]	8.0[b]	19.9[b]

[a] Includes initial leakers for items and totals of items.
[b] Includes warehouse samples.

3. Defects of Can Coatings (Table 6)

Practically the only defect observed in the "metallic" coatings of the 2½-gallon cans (CD1 and warehouse cans in Table 6) was removal by abrasion in handling the cases of cans during shipment and sampling. Ratings for this defect averaged 0.4 ± .2, lower than previous highest ratings by 0.5 at 70°/80%, 0.3 ± .2 at 70°/57%, and 0.1 at the lower temperatures. There was no peeling, and very little removal of coating by corrosion.

The predominant defect of the resinous type coating of the 5-gallon cans was uneven application, with some peeling immediately adjacent to "wiped" areas along seams. A small amount of loosening of coating by corrosion in thinly-applied spots and "wiped" areas was noted at 70°/80%. There was also some abrasion, but not enough to be considered a major defect. As seen in Table 6, mean ratings varied considerably by items. The general mean was 1.25 ± .42 at 70°/80%, with 0.8 ± .3 at other conditions. Individual ratings averaged lower than previous highs by 0.6 ± .3 at 0°F, and 0.4 ± .4 in the three higher-temperature rooms.

There was not, nor has there been on previous examinations, any evidence of softening of the coatings. The slight to moderate yellowish discoloration observed on some of the 5-gallon cereal item cans at 5 years was not seen at the present period. In general, all coatings appeared satisfactory for continued storage.

4. Corrosion of Cans (Tables 7 and 8)

External corrosion of can surfaces was practically all in the form of slightly pitted dark red spots of rust. Much of it was located at or near seams of the 5-gallon cans, where coating had been removed or failed to adhere to "wiped" areas near the solder lines. There was also some rust in thinly-coated spots, and some in areas where coating had been scraped thin or removed by abrasion in handling. The latter was apparently the only cause of corrosion on the 2½-gallon cans, which had no external solder except a few spots at the ends of the side seam.

The fact that practically all rust was dark red indicates that the corrosion was quite slow and long established--new rust is bright red. As seen in Table 7, 2½-gallon cans had relatively little except at 70°/80% (rating 1.3); the mean rating for cans of this type at 70°/57% was 0.3 ± .2, with 0.15 ± .05 at lower temperatures. Mean ratings were lower than previous highs by 0.1 ± .2, also indicating no "active" corrosion during the sixth year. The 5-gallon cans averaged 1.7 ± .8 at 70°/80%, 0.8 ± .5 at the 57% r.h. conditions, and 0.7 ± .3 at 0°F.

Internal corrosion was largely dark surface discoloration where product wrappers or unwrapped hard candies touched can walls. Practically all was of the "dark smudge" type, with very little pitting. As seen in Table 8, there was somewhat more of this in cans from 70°F than from lower temperatures, particularly in carbohydrate supplements. Otherwise differences

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TABLE 6

DEFECTS IN CAN COATINGS
(0-9 scale, 0 = none)

A. Cereal Item Cans Stored Six Years

Storage °F/% r.h.	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Initial	1.2	.5	1.0	.7	.6	.5	.28	.74
70/80	.3	1.2	.9	1.0	1.8	1.6	.32	1.13
70/57	.3	1.0	.8	.8	1.0	.8	.26	.78
40/57	.3	.7	.5	.6	.9	1.1	.24	.68
0/amb	.5	.5	.5	.3	1.0	.7	.17	.58
std.dif.,cans	.20	.23	.18	.37	.30	.18	-	.25
sign.dif., 5%	NS	.44	.34	NS	.59	.35	.39[a]	.17
Mean	.35	.85	.68	.68	1.18	1.05	.22[b]	.60

	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
	Warehouse Samples Transferred to Controlled Storage									
sample	.8	.6	.7	.8	.9	1.1	.3	.24	.40	.74
70/57	.8	.2	.3	.4	.4	.6	.2	.11	.18	.41

B. Carbohydrate Supplement Cans Stored Five Years

	CD11	CD12	CD14	std.dif. cans	Mean
	Items in Controlled Storage				
Initial	.5	.7	.5	.30	.57
70/80	1.8	.6	1.1	.39	1.17
70/57	1.3	.5	.9	.20	.90
40/57	1.1	.5	1.3	.39	.97
0/amb	.9	.5	1.2	.44	.87
std.dif.,cans	.53	.20	.27	-	.37
sign.dif., 5%	NS	NS	NS	.59[a]	NS
Mean	1.28	.53	1.13	.29[b]	.98

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

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TABLE 7

EXTERNAL CORROSION OF CANS
(0-9 scale, 0 = none)

A. Cereal Item Cans Stored Six Years

Storage °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Initial	.2	1.0	.0	1.0	.7	1.1	.51	.68
70/80	1.3	1.5	1.2	2.0	2.5	2.3	.29	1.80
70/57	.2	.6	.5	1.6	1.1	1.0	.17	.83
40/57	.2	.5	.3	.7	.8	1.4	.20	.65
0/amb	.1	.6	.5	.5	1.0	.9	.19	.60
std.dif.,cans	.18	.18	.23	.20	.25	.25	-	.23
sign.dif., 5%	.35	.35	.44	.40	.49	.49	.33[a]	.16
Mean	.45	.80	.63	1.20	1.35	1.40	.28[b]	.97

	Warehouse Samples Transferred to Controlled Storage								
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
sample	.3	.4	.3	.2	.5	.5	.2	.30	NS	.32
70/57	.3	.5	.1	.3	.4	.3	.2	.29	NS	.30

B. Carbohydrate Supplement Cans Stored Five Years

	Items in Controlled Storage				
	CD11	CD12	CD14	std.dif. cans	Mean
Initial	.5	.6	.2	.20	.41
70/80	2.6	.4	.9	.74	1.30
70/57	.9	.4	.5	.17	.60
40/57	.4	.6	1.9	.60	.97
0/amb	.5	.4	1.3	.82	.73
std.dif.,cans	.63	.15	.88	-	.63
sign.dif., 5%	1.23	NS	NS	1.01[a]	.46
Mean	1.10	.45	1.15	.49[b]	.90

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

TABLE 8

INTERNAL CORROSION OF CANS
(0-9 scale, 0 = none)

A. Cereal Item Cans Stored Six Years

Storage	Items in Controlled Storage							
°F/% r.h.	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Initial	1.0	1.3	.1	.6	.72	.46	.14	.71
70/80	.9	.9	.6	1.0	.9	1.0	.17	.88
70/57	1.0	1.2	.6	1.0	.8	.8	.22	.90
40/57	.6	1.1	.4	.8	1.0	.7	.31	.77
0/amb	.5	1.0	.4	.9	.7	.7	.24	.70
std.dif.,cans	.32	.15	.18	.25	.30	.18	-	.24
sign.dif., 5%	NS	.20	NS	NS	NS	NS	.34[a]	.13
Mean	.75	1.05	.50	.93	.85	.80	.17[b]	.81

	Warehouse Samples Transferred to Controlled Storage									
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
sample	.7	.5	.6	.1	.4	1.0	.7	.26	.43	.56
70/57	.3	.5	.8	.6	1.1	1.0	.5	.43	.72	.69

B. Carbohydrate Supplement Cans Stored Five Years

	Items in Controlled Storage				
	CD11	CD12	CD14	std.dif. cans	Mean
Initial	.5	.7	.4	.13	.55
70/80	1.4	1.1	1.0	.74	1.17
70/57	1.6	1.2	.9	.48	1.23
40/57	1.0	.8	.7	.12	.83
0/amb	1.1	.5	.8	.40	.80
std.dif.,cans	.75	.30	.23	-	.49
sign.dif., 5%	NS	.42	NS	.75[a]	.31
Mean	1.28	.9	.85	.33[b]	1.01

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

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were apparently item or can variations, as there was no consistent correlation with extent of wrapper damage in cereal products or with moisture content in any of the rations. The smaller cans averaged slightly less than the larger, but again there were large variations among individual items.

Supplement item CD11 averaged 0.4 ± .2 higher than at previous examinations and warehouse items varied as seen in the data. Other items averaged 0.4 ± .5 lower at 70°/80% and 0°/amb, 0.3 ± .4 lower at the 57% r.h. conditions. Thus internal corrosion apparently is not a serious problem, excepting some discoloration and a slight "metallic" taste in pieces of hard candy which were in contact with the unprotected walls of the cans.

Through the sixth year, no leaks have been attributed to any type of corrosion except some perforations resulting from dripping water in two Arkansas cave shelters inspected in 1966.

III. The Rations

A. Cereal Items

1. Condition of Packages (Tables 9 and 11)

Percentages of broken seals and torn packages were calculated from 15 packages per can for CD1 and the seven warehouse items, 24 for CD2, 7 and 8, and 126 for CD9 and 10. Only breaks large enough to allow one unit of product to slip out of the package were counted, thus omitting many small corner perforations which allowed some of the crackers or biscuits to touch the can wall.

Broken Seals. As seen in Table 9, broken seals apparently varied with individual cans, types of pack and types of wrapping materials, with little or no consistent time or temperature effect. Total breaks were higher than usual in the glassine packages of cracker CD8 (previous average 11.8%), lower in the light waxed paper of biscuit CD7 (previous average 2.9%). Results for cracker CD1 (glassine, quite variable, mean about 7%) biscuit CD2 (heavy waxed paper, no broken seals) and wafers CD9 and 10 (glassine, but compactly packed) averaged about the same as on previous examinations. Differences among warehouse samples were similar to, though not as great as, those among the items of the storage study.

Torn Packages. With the exception that the range of torn packages (0-97%) was greater among warehouse samples, tearing of the wrappers appeared to vary much as did breaking of seals; i.e., with type of wrapping material used, compactness of packing in cans, and handling "shocks" to which individual cans had been subjected. Data in Table 9 indicate that the wrapping materials of items CD2, WC5, WB8 and WB9 were definitely superior to those of items such as CD8, WC6, WB1 and WB10. The main differences were in brittleness of the material and amount of wax coating available for holding the seals.

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TABLE 9

PACKAGE DEFECTS IN CEREAL ITEMS STORED SIX YEARS
(as percent of packages)

Condition °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Unsealed Packages:								
Initial	.55	1.75	.00	2.45	.20	.73	2.09	.94
70/80	.0	20.8	.0	.0	.0	4.0	13.63	4.13
70/57	.0	35.4	.0	.0	.4	3.6	8.52	6.56
40/57	.0	16.7	.0	.0	.8	.8	6.84	3.04
0/amb	30.0	8.3	.0	2.1	1.6	.4	15.32	7.07
std.dif.,cans	16.67	22.92	-	2.09	.89	.98	-	11.62
sign.dif. 5%	26.74	NS	-	NS	NS	1.92	19.70[a]	NS
Mean	7.50	20.31	.00	.52	.70	2.18	8.48[b]	5.20
Torn Packages:								
Initial	.55	1.40	.00	3.83	.40	.07	3.64	1.04
70/80	.0	16.7	.0	4.2	.8	.0	14.03	3.60
70/57	.0	35.4	.0	.0	.8	.4	8.54	6.10
40/57	.0	66.7	2.1	4.2	.0	.0	24.12	12.15
0/amb	3.3	39.6	.0	25.0	.8	.0	35.51	11.45
std.dif.,cans	3.33	50.91	2.09	25.69	1.13	.40	-	22.98
sign.dif. 5%	NS	NS	NS	NS	NS	NS	38.97[a]	NS
Mean	.83	39.58	.52	8.33	.60	.10	16.77[b]	8.33

	Warehouse Samples Transferred to Controlled Storage								
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
Unsealed Packages:									
sample	10.0	16.7	3.3	6.7	10.0	16.7	20.0	19.80	NS	11.90
70/57	.0	6.7	13.3	.0	.0	3.3	13.3	14.48	NS	5.24
Torn Packages:									
sample	6.7	60.0	47.8	.0	3.3	96.7	10.0	19.63	32.82	32.06
70/57	.0	33.3	46.7	.0	.0	96.7	3.3	36.87	63.35	25.71

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Total Packages Broken. Comparison of the data of Table 9 with total breakage of packages in Table 11 shows that items WC5, WB8 and WB9 had no broken packages, with only 0.5% torn packages in CD2. Total seal breaks and torn packages were few in wafers CD9 and 10 (1.9%), somewhat higher in CD1 and 7 (8.6%), and moderately high in WB11 (16.7%), 13.3% of the latter being seal breaks.

Tearing of thin, brittle "glassine" caused most of the breakage in the four items having seriously defective packages. Cracker WC6 had 36.7% broken packages, 33.3% torn (70% with 60% torn at the first examination); biscuit WB1 had 46.7% broken, all torn; biscuit WB10 had 96.7% broken, all torn. Storage cracker CD8, the only item with more defective packages than on any previous examination, was relatively high in both types of breakage, having 39.7% torn (6.7% of which also had loose seals) and an additional 13.3% with broken seals. Thus it seems obvious that the thin, lightly-waxed, brittle wrapping materials should not have been used for the crackers or biscuits, which have sharp corners and fit loosely in the cans.

2. Breakage of Products (Tables 10 and 11)

As crackers and biscuits were baked in 2-unit or 4-unit layers, product breakage was calculated as separation at the score lines between units and fracture of individual units. Can totals used for these estimates were as follows:

	score lines	units		score lines	units
CD1	228	456	WB1	222	444
CD8	584	1168	WB8	198	396
WC5	924	924	WB9	788	788
WC6	232	464	WB10	198	396
CD2	1172	1172	WB11	204	408
CD7	1364	1364			

Wafers CD9 and CD10 both had 756 units per can, packed six per package as individual units without score lines.

Score Lines Broken. As on previous examinations, there was little or no indication of time or temperature effects on breaking of crackers or biscuits at score lines or crumbling of edges of wafers. Data in Table 10 illustrate the general magnitude and variations which have been observed in this type of breakage. As seen, variations are apparently characteristic of items, and undoubtedly reflect some effects of handling of the products during shipping and storage. Item means are near averages of earlier examinations for crackers, biscuits and wafer CD9; wafer CD10 averaged about 20% lower than at earlier periods.

Unit Breakage. Data given in Table 10 include 4.7% crushed units for cracker CD8 and 1.4% crushed for biscuit CD7; warehouse samples had 4.7% crushed in WB1 and 7.9% crushed in WB10. Eight of the twenty cans examined

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TABLE 10

PRODUCT BREAKAGE IN CEREAL ITEMS STORED SIX YEARS
(as percent of total unit)

Condition °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Score Lines Broken or Edges Chipped[a]:								
Initial	7.2	6.1	4.2	10.1	18.9	28.4	9.21	12.48
70/80	17.7	4.3	2.6	11.6	20.2	39.5	7.75	15.97
70/57	8.9	11.1	12.8	17.4	31.4	22.0	8.47	17.25
40/57	21.0	20.1	4.5	9.8	29.3	18.5	6.99	17.21
0/amb	37.4	5.1	5.9	7.3	26.1	26.9	11.24	18.11
std.dif.,cans	18.36	2.81	2.52	5.58	6.96	5.57	-	8.76
sign.dif., 5%	NS	5.51	4.94	NS	NS	10.93	14.77[b]	NS
Mean	21.24	10.17	6.45	11.50	26.72	26.74	6.40[c]	17.13
Unit Breakage:								
Initial	7.6	17.6	1.9	4.3	.4	.5	4.27	5.38
70/80	7.8	9.9	3.1	7.6	.0	.6	3.78	4.84
70/57	8.4	28.5	4.0	4.8	.0	.0	3.95	7.62
40/57	9.5	28.2	2.1	6.7	.0	.0	6.88	7.76
0/amb	15.7	18.3	1.7	4.4	.2	.0	6.71	6.71
std.dif.,cans	8.88	9.59	1.01	3.32	.20	.60	-	5.53
sign.dif., 5%	NS	NS	NS	NS	NS	NS	8.73[b]	NS
Mean	10.35	21.22	2.73	5.90	.05	.15	4.04[c]	6.73

	Warehouse Samples Transferred to Controlled Storage									
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
Score Lines Broken:										
sample	6.6	61.3	23.7	4.8	30.7	54.4	25.4	10.47	17.50	29.57
70/57	8.4	39.0	29.5	3.0	30.7	53.3	15.3	9.82	16.42	25.60
Unit Breakage:										
sample	5.3	38.7	20.0	6.8	10.4	2y.2	15.6	8.88	14.85	18.03
70/57	3.2	11.5	18.7	6.8	7.7	22.8	4.3	7.04	11.91	10.73

[a] Wafers CD9 and CD10 were separate units without score lines.
[b] Significant difference for items in rooms.
[c] Significant difference for item means.

in these four items had been dented in packing or shipping, apparently
contributing to the high percentages of package and product damage observed.
Among other high-damage items, crackers CD1 and WC6 and biscuit WB9 had
"cupped" to varying extents in the layers during baking, which was
probably the cause or one of the causes of the high score-line breakage
and moderately high unit breakage found in these samples. Unit breakage
for the other, more nearly "normal" storage and warehouse items was somewhat
lower than the means of previous examinations.

Total Product Breakage. The percentages of total product breakage
given in Table 11 include only half of the score-line breakage of Table 10
for items CD1, CD8, WC6, WB1, WB8, WB10 and WB11, as each of these had
twice as many units as score lines (i.e., baked in 2-unit layers). For
the other six items total breakage is the sum of score-line (or edge, CD9
and 10) and unit breakage.

In evaluating the detrimental aspects of breakage, the type of damage
must be considered. Only 0.1% of the total 26.8% damage to wafers was
broken units, 26.7% being crumbling of edges. As package damage averaged
only 1.8%, the crumbled edges would make little difference in utilization
of the wafers in shelter practice. Even the intact wafers crumble when
eaten, so the package would normally be used as a "dish" to retrieve all
of the crumbs as the ration is being consumed. Score-line breaks, which
ranged 3.0 to 53.3, mean 20.8% in the eleven cracker and biscuit items,
would also be no particular nuisance in servicable packages. Thus the
breakage observed in items CD2, WC5, WB8 and WB9 would offer no problem,
while that of CD7, WB11, and even CD1 (8.3% packages, 20.9% product) would
probably cause only minor inconvenience.

The "problem" items, therefore, would be those such as CD8, WC6, WB1
and WB10. These averaged 33.0 ± 15.7% broken score lines, 18.6 ± 4.4%
broken units (34.7 ± 9.1% total breakage) in packages with 10.9 ± 6.6%
broken seals, 54.1 ± 25.1% torn sides (58.3 ± 23.0% total package damage).
Distribution of rations damaged to this extent in a shelter would almost
be a process of picking out the paper and scooping out the pieces and
crumbs This, of course, illustrates the importance of using good,
adequately waxed wrapping materials, and handling cans and cases with
sufficient care to prevent crushing or shattering of the product.

One observation related to storage temperatures should be noted.
While neither temperature nor time has had any statistically demonstrable
influence on breakage, the standard differences of cans listed in Tables 9,
10 and 11 suggest increased variability resulting from handling the
rations at lower temperatures, particularly 0°F.

3. Appearance, Color and Texture (Table 12)

Sensory scores were assigned by five experienced judges who have a
performance record of reacting in similar manner to sample differences (mean
can variance ± .32), although tending to use somewhat different rating
levels (mean judge variance ± 1.36) on the 10-1 scale indicated in Table 12.

TABLE 11

TOTAL BREAKAGE IN CEREAL ITEMS STORED SIX YEARS
(as percent of packages and total units)

Condition °F/% r.h.	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Total Packages Broken:								
Initial	1.10	3.15	.00	3.83	.60	.80	5.11	1.58
70/80	.0	33.3	.0	4.2	.8	4.0	24.07	7.04
70/57	.0	62.5	.0	.0	1.2	4.0	1.17	11.28
40/57	.0	77.1	2.1	4.2	.8	.8	19.11	14.15
0/amb	33.3	39.6	.0	27.1	2.4	.4	39.91	17.13
std.dif.,cans	20.0	51.29	2.09	27.72	1.64	1.20	-	25.19
sign.dif., 5%	32.08	NS	NS	NS	NS	2.35	42.72[a]	NS
Mean	8.33	53.13	.52	8.85	1.29	2.28	18.39[b]	12.40
Total Units Broken:								
Initial	7.6	17.6	4.2	10.1	19.3	28.9	9.86	14.62
70/80	16.7	12.0	5.7	19.0	20.2	40.1	7.59	18.94
70/57	12.3	31.8	16.8	22.2	31.4	22.0	8.85	22.82
40/57	20.0	36.3	6.6	16.5	29.3	18.5	5.22	21.20
0/amb	34.2	19.9	7.6	11.7	26.3	26.9	11.70	21.08
std.dif.,cans	11.49	8.77	2.64	7.69	6.89	5.24	-	8.66
sign.dif., 5%	NS	12.17	5.18	NS	NS	10.29	14.85[a]	NS
Mean	20.92	24.97	9.18	17.35	26.77	26.89	6.32[b]	21.01

	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
Warehouse Samples Transferred to Controlled Storage										
Total Packages Broken:										
sample	16.7	70.0	48.9	6.7	13.3	96.7	30.0	27.52	47.81	40.32
70/57	.0	36.7	46.7	.0	.0	96.7	16.7	38.30	34.58	28.10
Total Units Broken:										
sample	11.8	65.7	31.9	9.2	39.2	55.5	28.3	12.30	20.56	34.54
70/57	11.7	31.0	33.4	8.3	38.4	49.5	12.0	8.17	13.66	26.32

[a] Significant difference for items in rooms.
[b] Significant difference for item means.

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Samples were presented four to six per session, two sessions per item, so duplicate cans were scored on different sessions. All samples were identified, and comparisons among storage conditions were invited in the comments.

Appearance-Color. As appearance and color have changed relatively little with storage, the scores shown in Table 12 vary more with product and can differences than with effects of storage. Average increases over previous low scores were $0.24 \pm .28$ at 70°F, $0.16 \pm .40$ at lower temperatures; corresponding comparisons to all previous scores showed decreases averaging $0.11 \pm .30$ at 70° and $0.41 \pm .34$ at 40° and 0°. Predominant reasons given for decreases were glazed appearance of surfaces, slight dulling, and in a few instances a slight darkening of samples at 70°F.

Texture. As seen in Table 12, texture scores varied with products and to some extent with temperatures--samples from 70°F were scored somewhat lower because of slightly increased hardness or brittleness. Scores shown averaged $0.30 \pm .38$ higher than previous low scores at 70°, $0.60 \pm .36$ higher at the lower temperatures. In fact, scores at six years were near averages for all previous examinations, being $0.14 \pm .29$ lower at 70°F and $0.03 \pm .23$ lower at 40° and 0°. Changes in texture have been small in comparison with product and item differences.

There was a tendency toward pattern scores for texture of the CD items. Correlations of texture with appearance and with color were as follows:

texture with:	Appearance	Color
	r	r
70°/80%	+.817[b]	+.330[NS]
70°/57%	+.343[b]	+.725[b]
40°/57%	+.800[b]	+.578[a]
0°/amb	+.744[b]	+.500[NS]
All CD	+.738[b]	+.501[b]
Warehouse (70°/57%)	-.020	.000[NS]

NS = not significant
a = significant at 5% level of probability
b = significant at 1% level of probability

The judges knew the storage arrangement of the CD items, and apparently scored appearance and texture accordingly: color varied somewhat more than appearance (slight glazing at 70°), and correlations of texture and color were lower. No such pattern had been established with the warehouse samples, which may have resulted in the almost complete lack of correlations with texture.

4. Hunter Color Values (Table 13)

Color values were determined on duplicate samples from each can, chopped and sieved to 14-mesh, using a Hunter type color and color difference meter set with NBS reference Maize (L = 73.8, a = 1.4, b = 31.4).

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TABLE 12

APPEARANCE-COLOR AND TEXTURE SCORES OF CEREAL ITEMS STORED SIX YEARS
(scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Appearance-Color:								
Initial	6.5	7.0	8.2	8.3	7.7	6.5	.44	7.37
70/80	7.15	6.4	7.35	7.05	6.45	6.75	.28	6.86
70/57	7.05	6.4	7.15	6.95	6.35	6.2	.27	6.68
40/57	7.2	6.15	7.2	7.05	6.4	6.35	.33	6.73
0/amb	7.15	6.15	7.2	7.05	6.5	6.4	.35	6.74
std.dif.,cans	.32	.46	.10	.27	.22	.34	-	.31
sign.dif., 5%	NS	NS	.16	NS	NS	NS	.54[a]	NS
Mean	7.14	6.28	7.23	7.03	6.43	6.43	.22[b]	6.75
Texture:								
Initial	6.5	7.4	7.8	8.2	6.2	5.8	.44	6.98
70/80	6.3	6.2	7.1	7.2	6.1	5.9	.40	6.47
70/57	7.3	6.0	7.2	7.3	6.0	5.8	.20	6.60
40/57	7.1	6.7	7.5	7.7	6.2	6.0	.33	6.87
0/amb	7.2	6.8	7.4	7.7	6.3	5.9	.22	6.88
std.dif.,cans	.18	.30	.15	.52	.32	.15	-	.30
sign.dif., 5%	.35	.61	.28	NS	NS	NS	.22[a]	.18
Mean	6.98	6.43	7.30	7.48	6.15	5.90	.48[b]	6.70

	Warehouse Samples Transferred to Controlled Storage									
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
Appearance-Color:										
sample	7.05	6.5	7.35	6.3	7.2	6.1	6.95	.30	.50	6.78
70/57	7.3	6.7	7.45	6.55	7.15	6.55	6.75	.29	.49	6.92
Texture:										
sample	6.3	5.8	7.3	7.8	6.9	6.8	5.8	.32	.54	6.67
70/57	7.3	6.6	7.3	8.0	7.2	7.0	7.0	.33	.54	7.20

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Hunter L. The L or "lightness" values shown in Table 13 average 0.2 higher than previous high values at 0°F and 0.2 lower than previous highs at other conditions. The color meter, as noted, was apparently reading about 1.0 units higher than formerly. Thus the 0°F values were apparently about 0.8 under previous highs and the other samples about 1.2 under; the average was still 2.6 above initials, however. This resulted from tendency of the surface to glaze, with some slight fading effect remaining in most of the products.

Direct comparisons show biscuits, particularly CD7, had lower L values at 70°/80% than at lower temperatures (average 1.3 ± 1.0 lower). This reflects darkening and dulling, CD7 at 70°/80% being about 3.5 units below previous high value and only about 1.0 unit above initial. Other samples averaged higher at both 70°F conditions (by 2.4 ± 2.1 units for crackers and 1.5 ± 0.9 units for wafers) than at 40° and 0°F, indicating that the tendency for fading at higher temperatures was still predominant. Most of the score panel judges did not consider this a disadvantage, as it merely reduced the extent of overbrowning in many of the samples. Warehouse samples averaged increasing about 0.9 ± 1.1 during controlled storage at 70°/57%, during the fifth and sixth years after manufacture.

Hunter "a". The "a" value indicates red component when positive, as all samples were at the current period. Fading of red was a characteristic change in 100°F storage, but this has not been so definite at 70°F. Also, some items are darker than others, and these exhibit somewhat different changes; cracker CD1 and wafer CD10 are darker than other crackers or wafers.

In changes from initial values as shown in Table 13, the darker items averaged 0.8 ± .3 paler at 70°F and 0.3 ± .2 paler at 40° and 0°, while cracker CD8, biscuits CD2 and 7 and wafer CD9 averaged 0.1 ± .5 darker than initial at 70°F and 0.4 ± .3 darker at the lower temperatures. Thus a temperature difference of about 0.4 unit was apparently present, but there was about 0.8 unit difference in the manner in which darker items (which faded) and lighter items (which darkened) reacted to it.

In comparing values at six years to previous low (fading tendency) values, CD1 and 10 averaged 0.7 ± .1 higher than lowest values at 0°, 0.3 ± .3 higher at the other temperatures; the lighter items were 0.9 ± .6 above lowest readings at 0° and 1.2 ± .6 above previous lows at 40° and 70°F. Conversely, in comparing present and previous high values, the darker items averaged 0.8 ± .2 lower than former highs at 0°F and 1.0 ± .4 lower at warmer conditions, while corresponding differences for lighter items were 0.6 ± .4 under highs at 0°F but only 0.2 ± .4 under at cool and room temperature conditions. Finally, in directly comparing present "a" values at 0°F with those above 0°, crackers and wafers averaged 0.1 ± .3 lower at 40° and 0.6 ± .4 lower at 70°, whereas biscuits had no consistent trend, averaging 0.0 ± .4 difference between 0° and other temperatures.

Differences of this magnitude may appear small and easily confusing, but the trained score panel judge can easily detect the fading of the darker samples, and sometimes the darkening of the lighter items, usually considering

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the fading desirable and the darkening otherwise. Thus the marked changes in "redness" observed as fading at 100°F are apparently taking place at a lesser rate in rations stored at 70° and in a few instances even at 40°, while some of the paler items are tending to darken slightly at the moderate to low temperatures. This may also be seen in the changes in warehouse samples at 70°/57%.

Hunter b. Hunter b, or yellow component in cereal items, typically changes less than L or "a" values except in browning reactions. In the six storage items presently being considered, "b" values remained fairly constant through about the fourth year, with high levels averaging 0.6 ± .4 above initial values at 24 ± 18 months. At 48 months, average b value was 0.1 ± .5 above initial at 70°F, 0.3 ± .7 above initial at other conditions. During the fifth year, as noted in Table 13, repair of the b-assembly of the color meter resulted in an apparent down-shift of about 1.4 NBS units in the readings. Thus all "b" values were apparently lower than initial at 60 and 72 months; the average difference between 60-month and 72-month readings at 70°F and below was less than 0.1 unit.

Correcting the "b" values for the apparent shift indicates crackers were 0.8 ± .4 lower than initial at 70°F, crackers at lower temperatures and biscuits at all conditions averaged no change, and wafers at all conditions averaged 0.6 ± .3 higher than initial. The crackers at 70°F are, therefore, the only storage items which exhibit any suggestion of the color change usually associated with browning reactions, and this may be considered questionable under the circumstances involved in the estimates of changes. If corresponding corrections are made for the warehouse samples, crackers decreased 1.0 ± .2 and biscuits averaged no change, very close to the estimates made for the storage study items.

Hunter a/b ratio. If the a/b values shown in Table 13 were also corrected for the apparent shift in "b" values which resulted from altering the color meter, ratios would be reduced by .005 for CD1, .008 for CD8 and 7, .012 for CD2 and 9, and .023 for CD10. Warehouse ratios would be lower than shown by .008 for crackers and .014 for biscuits. The ratios then indicate the predominant types of changes (except the suggestion of browning in crackers at 70°F--increases in ratio can result from increased "a" as in darkening or "dulling" of color, or from decreases in "b" as in browning). As seen, crackers CD1 and WC6, biscuit WB1 and wafer CD10 tended to fade (decreased ratio) at higher temperatures, while darkening was apparently the predominant change in other items.

5. Fracture Strength (Table 14)

Ten units selected in a systematic manner from each can were used to determine fracture strength. Each unit was supported by four corner blocks of about 1/16 sq. in. area and the dull point of a weighted plunger was rested on the center of the unit. The plunger carried fixed weights varying from 400 to 1900 grams, depending on the fracture resistance of the unit, and additional weight was added to the point of fracture by applying increasing pressure on the plunger with a 1000-gram spring-loaded pressure tester.

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TABLE 13

HUNTER COLOR VALUES OF CEREAL ITEMS STORED SIX YEARS
(NBS Units)

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Condition °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
L Values:								
Initial	61.8	68.8	68.7	69.6	60.8	55.2	1.63	64.12
70/80	66.6	75.7	72.5	71.5	63.6	60.0	1.04	68.31
70/57	65.2	73.4	73.8	74.0	64.6	59.0	.94	68.32
40/57	65.4	70.7	72.7	73.8	63.1	56.9	.55	67.10
0/amb	65.2	70.0	73.0	73.6	63.1	58.0	.46	67.17
std.dif.,cans	1.25	.22	.62	.78	.71	.76	-	.79
sign.dif., 5%	NS	.42	.99	1.53	1.14	1.49	1.26[a]	.47
Mean	65.59	72.47	73.00	73.21	63.59	58.48	.58[b]	67.72
"a" Values:								
Initial	5.1	2.6	2.0	2.5	3.7	5.0	.74	3.47
70/80	4.3	2.0	2.0	3.4	4.0	4.0	.27	3.27
70/57	4.3	2.9	2.1	2.3	3.8	4.2	.29	3.27
40/57	4.5	2.9	2.3	2.8	4.3	4.9	.24	3.63
0/amb	4.9	3.3	1.9	3.1	4.1	4.7	.43	3.65
std.dif.,cans	.37	.39	.30	.33	.25	.20	-	.32
sign.dif., 5%	NS	.76	NS	.65	NS	.39	.51[a]	.19
Mean	4.49	2.76	2.08	2.89	4.05	4.45	.23[b]	3.45

	Warehouse Samples Transferred to Controlled Storage									
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
L Values:										
sample	71.3	61.9	68.3	64.6	69.0	69.3	73.3	1.05	1.75	68.25
70/57	73.2	63.6	72.3	67.3	70.4	70.1	74.0	1.01	1.70	70.13
"a" Values:										
sample	1.8	5.1	4.3	1.5	-.1	3.0	.8	.42	.70	2.34
70/57	3.8	4.5	3.5	3.4	3.0	3.2	2.4	.27	.45	3.40

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(continued)

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TABLE 13 (continued)

Condition °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
"b" Values:								
Initial	25.0	21.9	19.9	22.0	21.3	19.5	.43	21.63
70/80	23.9	19.5	17.9	21.2	20.7	17.9	.35	20.18
70/57	23.7	19.8	17.8	20.6	20.3	18.3	.47	20.10
40/57	24.2	20.4	18.0	20.4	21.1	18.5	.44	20.43
0/amb	24.9	20.6	17.6	20.8	20.5	17.9	.39	20.38
std.dif.,cans	.68	.29	.27	.41	.30	.40	-	.42
sign.dif., 5%	NS	.56	NS	NS	.48	NS	.68[a]	.26
Mean	24.19	20.06	17.83	20.74	20.64	18.16	.31[b]	20.27
a/b Ratios:								
Initial	.203	.120	.097	.115	.173	.256	.034	.161
70/80	.178	.100	.114	.159	.192	.225	.016	.162
70/57	.181	.145	.118	.113	.188	.230	.015	.163
40/57	.187	.142	.128	.138	.203	.267	.014	.177
0/amb	.197	.162	.105	.147	.201	.259	.022	.179
std.dif.,cans	.034	.019	.018	.018	.015	.014	-	.017
sign.dif., 5%	NS	.037	NS	.029	NS	.027	.027[a]	.010
Mean	.186	.138	.116	.139	.196	.245	.013[b]	.170

Condition °F/% r.h.	Warehouse Samples Transferred to Controlled Storage									
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
"b" Values:										
sample	23.2	24.1	21.2	19.7	20.0	20.3	19.8	.49	.82	21.18
70/57	20.9	22.6	19.4	18.4	18.3	18.6	18.2	.24	.40	19.49
a/b Ratios:										
sample	.076	.211	.204	.075	-.004	.148	.042	.020	.034	.111
70/57	.182	.199	.180	.186	.164	.171	.132	.016	.027	.174

[a] Significant difference for items in rooms.
[b] Significant difference for item means.
[c] The b-assembly of the color meter was repaired during the fifth year, and the meter was also checked and adjusted during the sixth year. The results were an apparent down-shift of about 1.4 NBS units in "b" readings and an increase of about 1.0 unit in L readings, respectively.

Cracker CD1 averaged 260 grams higher than previous average and 100 grams higher than previous high values--the reason for the increase was not apparent, except this item has been increasing at every examination from mean low of 1350 grams at 36 months. All other storage crackers have also increased since the first to second year (CD3 from 1020 to 1110, CD5 from 1240 to 1500, CD8 from 1120 to 1315 for the last three examinatikns).

Biscuits have been less definite in trend, averaging low at 2 years and high at 4; CD2 averaged 1670 through 5 years as compared to the 1640 average at 6 years, but CD7 is currently below any previous periodic average with 5-year average of 1205. Wafers have also varied, with lows at 1 and 4 years, highs at 3 and 5 years; 5-year averages were 2235 for CD9 and 1560 for CD10.

No temperature influence has been observed in any item. The only characteristic variation is apparently with baking. Cracker CD1 is darker and tougher than the moderately baked CD8; biscuit CD2 is tougher than would be expected (apparently hardened in a low-temperature oven), since it is not browner than CD7; wafer CD9 is more compact than the "toasted" wafer CD10.

6. Moisture Content (Table 14)

Moisture content was determined on duplicate 14-mesh samples from each can as loss of weight after heating 5-gram aliquants 24 hours at 70°C under a 29-inch vacuum.

As on earlier examinations, moisture contents apparently varied only with items and cans. Mean contents given in Table 14 are within about 0.1% of those of the last examination and of all previous examinations.

Leaking cans averaged higher than duplicate non-leakers by 0.74 ± .52% in the 70°/80% condition, but by only 0.12 ± .09 at 0°F/ambient r.h., the latter being a "wetter" room with respect to equilibrium moisture. In the 57% r.h. conditions, leakers varied by 0.25 ± .35%, non-leakers by 0.05 ± .04%, so the only consistent influence of leakers was apparently a greater fluctuation of moisture contents. The general mean for all leaking cans was 3.09 ± .27%, as compared to 2.83 ± .31% for duplicate non-leakers, but 3.10 ± .27 for all non-leakers. There was apparently poor correlation between leaking on leak test and the actual amount of moisture exchange which probably has taken place between rations and outside atmosphere in most of the crackers and biscuits.

There was no consistent correlation of moisture content with fracture strength, some items and rooms having positive coefficients, some negative, most non-significant, and none following any pattern with relation to previous examinations.

7. Rancidity Values (Table 15)

Peroxides. Peroxide values were determined by extracting fat from the ration samples with chloroform, mixing aliquants of the extract with 1.5

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TABLE 14

FRACTURE STRENGTH AND MOISTURE CONTENT OF CEREAL ITEMS STORED SIX YEARS

Condition	Items in Controlled Storage							
°F/% r.h.	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean

Fracture Strength, grams:[a]

	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Initial	1410	1140	1530	1295	2160	1285	198	1470
70/80	1721	1229	1646	1030	2596	1433	139	1609
70/57	1774	1205	1581	1120	2051	1659	122	1565
40/57	1731	1265	1622	1160	1936	1627	73	1557
0/amb	1794	1288	1699	1068	2136	1481	54	1578
std.dif.,cans	69	78	50	103	184	79	-	103
sign.dif., 5%	NS	NS	80	NS	361	154	173[b]	NS
Mean	1755	1247	1637	1095	2180	1550	76[c]	1577

Moisture Content, percent:[a]

	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Initial	1.85	3.53	1.91	1.96	4.01	4.03	.36	2.88
70/80	2.85	3.25	2.39	1.59	3.94	3.81	.59	2.97
70/57	2.50	3.26	2.71	2.19	3.94	4.01	.49	3.10
40/57	2.74	2.96	2.51	2.24	4.20	4.13	.26	3.13
0/amb	3.24	2.93	3.39	2.07	3.93	3.75	.12	3.22
std.dif.,cans	.87	.34	.23	.24	.02	.08	-	.41
sign.dif., 5%	NS	NS	.45	.38	.03	.15	.65[b]	NS
Mean	2.83	3.10	2.75	2.02	4.00	3.93	.30[c]	3.10

	Warehouse Samples Transferred to Controlled Storage								
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean

Fracture Strength, grams:[a]

	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
sample	1070	1225	1402	1346	1306	1460	1331	86	144	1306
70/57	1133	1176	1398	1485	1589	1534	1431	91	160	1392

Moisture Content, percent:[a]

	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
sample	2.82	2.97	1.12	2.68	2.60	3.05	3.09	.14	.24	2.62
70/57	2.56	2.68	1.58	2.70	2.46	2.82	2.82	.17	.28	2.51

[a]Leaking cans, observed in 17 of the 31 sets of duplicate samples, apparently had no consistent influence on fracture strength, and very little on mean contents of moisture.
[b]Significant difference for items in rooms.
[c]Significant difference for item means.

volumes of glacial acetic acid, reacting with potassium iodide, and titrating liberated iodine with potassium thiosulfate. As peroxides are unstable early-stage intermediate products in the complex patterns of fat oxidation, these patterns can be evaluated only in relation to changes in levels of peroxide values and other characteristics of the samples involved.

As discussed in the preceding report of this study (Tech. Rpt. 156-VI-GES, June, 1968, pp. 28-29), peroxidation of fats in cereal rations was stimulated somewhat by formulation, baking and canning, then decreased to very low levels during the second to third year of storage. Following this period of stability, a second period of active oxidation began at about the fourth year, with the result that items stored at 100°F were considered unsuitable for further use after about five years, and several items were judged quite stale after six years at 70°F. A summary of this upswing in oxidation, as indicated by increases in peroxide values, is as follows:

	18-24 months		36-48 months		60 months		72 months	
	crackers biscuits	wafers	crackers biscuits	wafers	crackers biscuits	wafers	crackers biscuits	wafers
100°F	1.0 ± .3	.1 ± .1	3.0 ± .5	1.6 ± 1.0	13.4 ± 6.0	1.9 ± .3	14.4 ± 8.6[a]	4.2 ± 1.9[a]
70°F	.2 ± .1	.2 ± .1	2.4 ± .8	2.1 ± .6	11.8 ± 5.4	4.2 ± 2.4	22.1 ± 7.7	5.6 ± 1.2
40°F	.1 ± .1	.3 ± .1	1.4 ± .6	2.2 ± .3	3.8 ± .9	6.8 ± 1.8	6.3 ± 2.8	13.2 ± 8.5
0°F	.1 ± .1	.2 ± .1	1.1 ± .6	1.2 ± .2	2.6 ± .5	3.2 ± .3	4.1 ± .9	3.3 ± .9

[a]From the preliminary sampling of August 1968, discussed on p.2.

Both the general increase in oxidation, and the tendency for peroxide accumulation to shift to lower temperatures (70°F in crackers and biscuits, 40°F in wafers) as oxygen became depleted and reactions progressed to secondary types of oxidation, are clearly indicated. Stale and rancid flavors, which result from the secondary reactions, have generally followed this oxidation pattern in crackers and biscuits. Wafers, with proportionally less oxygen and apparently a more "absorptive" structure for reaction products have remained lower in peroxide values at higher temperatures and exhibited less difference in flavor at the various conditions.

As seen in Table 15, warehouse crackers and biscuits, increasing from 7.5 ± 3.5 to 14.5 ± 4.8 during the fifth and sixth years, apparently followed about the same pattern as the storage study items. There are indications, however, that rations presently stored in warehouses with varying and fluctuating temperatures may not be in as good condition as are the rations being held in uniform storage. The mean peroxide value for crackers and biscuits from 70°F at 6 years in the storage study was 22.1 ± 7.7; warehouse samples examined during the sixth year averaged 79.8 ± 41.0. Wafers were apparently in better condition, C89 averaging 11.7 ± 7.1 at 70° and 40°F in the storage study as compared to 11.2 ± 5.9 in the warehouse sampling. (Warehouse sample averages calculated from data in report, US Army Natick Laboratories to Director, Defense Supply Agency, 11 Oct 1968).

TABLE 15

RANCIDITY VALUES OF FATS FROM CEREAL ITEMS STORED SIX YEARS

Condition °F/% r.h.	Items in Controlled Storage						std.dif. cans	Mean
	CD1	CD8	CD2	CD7	CD9	CD10		
Peroxide Values, milliequivalents per kilogram:[a]								
Initial	1.1	.8	1.1	.8	2.0	1.4	.43	1.20
70/80	20.9	14.2	25.1	15.2	6.7	5.0	5.82	14.52
70/57	29.9	22.6	36.1	12.7	6.6	3.9	4.44	18.63
40/57	10.3	7.4	4.3	3.2	21.7	4.7	2.48	8.59
0/amb	4.2	4.5	5.0	2.7	5.1	1.4	1.81	3.80
std.dif.,cans	2.33	4.03	6.38	4.69	2.22	2.11	-	3.95
sign.dif., 5%	4.57	7.90	12.52	9.21	4.36	NS	6.45[b]	2.36
Mean	16.32	12.17	17.61	8.44	10.01	3.76	2.89[c]	11.38
Free Fatty Acids, percent as oleic acid:[a]								
Initial	.17	.36	.16	.28	.34	.32	.028	.271
70/80	.17	.35	.20	.35	.48	.40	.027	.323
70/57	.22	.41	.19	.32	.52	.42	.026	.347
40/57	.17	.29	.15	.35	.46	.38	.012	.299
0/amb	.19	.30	.15	.31	.41	.34	.013	.283
std.dif.,cans	.017	.022	.015	.026	.028	.012	-	.021
sign.dif., 5%	.032	.043	.030	NS	.054	.024	.033[b]	.013
Mean	.188	.338	.172	.333	.464	.384	.015[c]	.313

	Warehouse Samples Transferred to Controlled Storage							std.dif. cans	sign.dif. 5%	Mean
	WC5	WC6	WB1	WB8	WB9	WB10	WB11			
Peroxide Values, milliequivalents per kilogram:[a]										
sample	9.5	9.4	.3	6.3	9.4	11.5	6.0	2.24	3.75	7.48
70/57	19.9	22.8	12.8	10.3	13.4	13.7	8.6	2.70	4.52	14.50
Free Fatty Acids, percent as oleic acid:[a]										
sample	.24	.13	.26	.20	.41	.31	.31	.022	.036	.265
70/57	.35	.18	.29	.20	.44	.36	.36	.018	.030	.311

[a] Peroxide values in leaking cans averaged 3.21 higher at 70°F and 0.62 higher at 47° and 0° than in non-leakers. Duplicate can differences were 4.48 at 70°, 2.48 at lower temperatures for leakers, 4.30 at 70° and 0.67 at lower temperatures for non-leakers. Leaking cans did not vary consistently from non-leakers in free fatty acid values.
[b] Significant difference for items in rooms.
[c] Significant difference for item means.

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Free Fatty Acids. These were determined by combining equal volumes of neutral ethanol with the chloroform extracts of fats and titrating with ethanolic alkali. As products of fat hydrolysis, free fatty acids are generally proportional to temperature and moisture content, and the higher values for wafers as given in Table 15 could be associated with the higher moisture content of this product. Cracker CD8 averaged only 3.1% moisture, however, and biscuit CD7 only 2.0% so fats were apparently less stable in these items than in cracker CD1 and biscuit CD2.

With the exception of the samples at 100°F, which reached high values at 4 to 6 years (means shown on p. 2 for sampling in August 1968 were .10 ± .15 lower than previous highs for crackers, .33 ± .24 above previous highs for biscuits, .05 ± .14 above previous highs for wafers), free fatty acids have changed relatively little from initial levels. Changes from initial and from 5-year values for the data shown in Table 15 and the August 1968 sampling at 100°F, were as follows:

	crackers		biscuits		wafers	
	from initial	from 5 yrs	from initial	from 5 yrs	from initial	from 5 yrs
100°F	.37 ± .07	.02 ± .04	.59 ± .21	.24 ± .04	.63 ± .02	.00 ± .01
70°F	.02 ± .03	.03 ± .04	.05 ± .02	-.02 ± .03	.13 ± .04	.01 ± .02
40°&60°F	-.03 ± .04	.01 ± .05	.02 ± .04	.01 ± .04	.07 ± .04	.00 ± .03

With variations in initial values ranging from ± .01 for wafers to ± .20 for biscuits, it is apparent that differences in individual items have been one of the primary sources of variance. Temperature has been another cause of variations, with higher values at 100°F and in some instances at 70°F. There is also a suggestion of differences associated with moisture content. Considering that free fatty acids should oxidize more readily than intact fats, but that excess moisture usually tends to retard oxidation, the apparent stability of the lower-moisture crackers and biscuits at 70°F and below may result from a balance between rates of oxidation and hydrolysis. Higher free acid values in wafers would thus be expected from their higher moisture content, which would shift the balance toward a relatively greater rate of hydrolysis. The combined effects of higher moisture and higher temperatures have been readily apparent in the high free acid values from 100°F storage.

Data in Table 15 show an increase of .05 ± .04% during 2 years of controlled storage of warehouse samples at 70°F. The 1968 warehouse sampling by NALABS, referred to above, averaged .15 ± .10% above initial for crackers and biscuits and .22 ± .02% above initial for wafer CD9 (four samples averaged .04 ± .01, 11 averaged .20 ± .07). As these are greater than the increases in 70° controlled storage, the net temperature effect in warehouses is obviously somewhat above 70°F.

8. Sensory Scores for Aroma and Flavor (Table 16)

All sensory scores were obtained as described above in section 3.

Aroma. Changes in aroma have been relatively small since the third year at 70°F, and through the six years at lower temperatures, although there

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TABLE 16

AROMA AND FLAVOR SCORES OF CEREAL ITEMS STORED SIX YEARS
(scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Items in Controlled Storage							
	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Aroma:[a]								
Initial	7.0	6.4	7.7	6.4	6.0	6.4	1.57	6.65
70/80	5.2	5.0	4.6	5.0	4.6	5.9	.53	5.05
70/57	6.5	5.2	5.3	5.5	4.9	5.6	.47	5.50
40/57	6.8	6.7	7.2	6.5	5.3	6.0	.49	6.42
0/amb	7.3	6.7	7.3	7.0	5.8	6.6	.43	6.78
std.dif.,cans	.71	.25	.62	.51	.32	.23	-	.48
sign.dif., 5%	1.14	.49	1.22	1.01	.63	.44	.81[b]	.29
Mean	6.45	5.90	6.10	6.00	5.15	6.03	.35[c]	5.94
Flavor:[a]								
Initial	6.0	6.4	8.4	7.8	6.2	5.4	1.51	6.70
70/80	5.6	5.1	5.5	5.3	5.3	5.6	.37	5.40
70/57	6.4	5.7	6.0	5.8	5.2	4.8	.41	5.65
40/57	6.6	6.3	6.4	6.3	5.7	5.5	.37	6.13
0/amb	6.8	6.7	6.9	6.7	6.3	6.2	.37	6.60
std.dif.,cans	.40	.20	.32	.52	.44	.30	-	.38
sign.dif., 5%	.79	.40	.63	.73	.70	.59	.63[b]	.23
Mean	6.35	5.95	6.20	6.03	5.63	5.53	.28[c]	5.95

	Warehouse Samples Transferred to Controlled Storage								
	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
Aroma:										
sample	4.5	6.0	6.6	6.4	5.7	5.3	6.0	.66	1.11	5.79
70/57	4.6	5.0	6.2	6.6	4.9	4.8	5.0	.41	.69	5.42
Flavor:										
sample	5.9	5.2	6.8	6.5	5.2	5.3	5.8	.58	1.01	5.81
70/57	5.5	5.7	6.1	6.5	4.8	5.3	6.1	.97	1.30	5.72

[a]Leaking cans averaged 0.2 lower than non-leakers in flavor, but there were no consistent differences in aroma.
[b]Significant difference for items in rooms.
[c]Significant difference for item means.

has been considerable fluctuation among items. Mean differences between the aroma scores shown in Table 16 and initial and 4-5 year scores (the latter including scores of warehouse samples) were as follows:

	crackers		biscuits		wafers	
	from initial	from 4-5yr	from initial	from 4-5yr	from initial	from 4-5yr
70°F	-1.2 ± .5	-.1 ± .5	-1.9 ± .9	-.5 ± .5	-.9 ± .4	.8 ± .7
40°F	.0 ± .3	.1 ± .4	-.2 ± .3	.5 ± .7	-.5 ± .2	-.1 ± .4
0°F	.3 ± .0	.0 ± .2	.1 ± .5	.4 ± .3	.0 ± .2	-.2 ± .4

Comments indicated the judges considered samples from 70°F to be flat and slightly stale in aroma, but not objectionable.

Flavor. The changes in flavor have been about the same as those in aroma, the greatest differences being in the initial scores of cracker CD1, scored 1.0 lower than aroma, and in the biscuits, scored 0., higher for CD2 and 1.4 higher for CD7. The mean differences from initial, and from 4-5 year scores (again including warehouse samples) were:

	crackers		biscuits		wafers	
	from initial	from 4-5yr	from initial	from 4-5yr	from initial	from 4-5yr
70°F	-.5 ± .7	.3 ± .5	-2.4 ± .4	.1 ± .6	-.6 ± .5	.7 ± .6
40°F	.2 ± .4	.0 ± .2	-1.7 ± .3	.0 ± .5	-.2 ± .3	-.2 ± .3
0°F	.5 ± .3	.0 ± .4	-1.3 ± .2	-.2 ± .2	.4 ± .4	.0 ± .4

As for aroma, flatness and staleness were noted as the reasons for reduction of scores at 70°F, but average scores for 70° samples were above those for 4-5 years, so there was no recommendation for discontinuation of storage at this temperature.

9. Hedonic Ratings for Aroma, Flavor and Palatability (Table 17)

The hedonic rating panel consisted of 25 judges selected as available from a pool of about 100 persons. Samples were presented in sets of six, five or four per session, each set containing one can from each of the four storage conditions plus two, one or no cans from warehouse samples. Thus duplicate cans from each item were rated on different sessions. Samples on each presentation were coded and randomized on a 6 X 25, 5 X 25, or 4 X 25 block plan to equalize sequence of rating among the various judges. The scale was the usual 9-point "like-dislike" range, with direct sample comparisons and comments invited.

Aroma. The data in Table 17 differ from initial and 4-5 year ratings, including warehouse samples, as follows:

	crackers		biscuits		wafers	
	from initial	from 4-5yr	from initial	from 4-5yr	from initial	from 4-5yr
70°F	-1.19 ± .52	-.48 ± .35	-1.11 ± .37	-.19 ± .45	-.55 ± .05	.16 ± .23
40°F	-.30 ± .37	-.16 ± .13	-.20 ± .05	.57 ± .60	-.39 ± .02	-.18 ± .14
0°F	-.30 ± .25	-.37 ± .33	-.06 ± .01	.53 ± .37	-.09 ± .19	-.23 ± .19

As seen, variations among items were fairly large at 70°F, and can differences were moderately large at lower temperatures, but the continuing decrease in aroma rating at 70°F seems fairly definite. Other ratings were less definite, biscuits at lower temperatures averaging .55 higher than previously but with large variations, and wafers averaging near previous rating at all temperatures.

Flavor. Comparisons with initial and 4-5 year ratings, as described above, were as follows for flavor ratings:

	crackers		biscuits		wafers	
	from initial	from 4-5yr	from initial	from 4-5yr	from initial	from 4-5
70°F	-.99 ± .38	-.32 ± .32	-1.18 ± .39	.10 ± .54	-.64 ± .18	-.06 ±
40°F	-.49 ± .25	-.32 ± .25	-.40 ± .20	.83 ± .67	-.64 ± .22	-.49 ±
0°F	-.50 ± .11	-.48 ± .40	-.35 ± .05	.65 ± .67	-.15 ± .28	-.44 ±

While all ratings except wafers at 0°F were definitely below initial, trends during the last two years were quite variable. Crackers tended to decrease at all conditions, while biscuits merely fluctuated at 70°F and increased, quite variably, at lower temperatures; both crackers and biscuits averaged around .4-.5 below initial at 40° and 0°F. Wafers, on the other hand, averaged about .6 below initial at 70° and 40°F, remaining near initial at 0°F, with fluctuations at 70° and decreases at lower temperatures. Apparently item and can variations have influenced scores about as much as storage has, except in crackers and biscuits at 70°F.

Palatability. The ratings in Table 17, as usual averaging somewhat higher than aroma and flavor scores, were related to initial and 4-5 year data as follows:

	crackers		biscuits		wafers	
	from initial	from 4-5yr	from initial	from 4-5yr	from initial	from 4-5
70°F	-.92 ± .44	-.14 ± .34	-1.04 ± .36	.28 ± .34	-.47 ± .32	-.01 ± .1
40°F	-.59 ± .39	-.14 ± .20	-.46 ± .14	.64 ± .47	-.49 ± .28	-.42 ± .1
0°F	-.64 ± .29	-.40 ± .32	-.46 ± .01	.48 ± .44	-.09 ± .43	-.39 ± .3

As for flavor, palatability ratings were definitely below initial for all samples except wafers at 0°F. Crackers at 0° and wafers at 40° and 0° decreased during the last two years, while biscuits increased about .55 at these temperatures, though still averaging .46 below initial ratings. Other samples, crackers at 40°F and all items at 70°, tended to fluctuate with no definite trend since about the fifth year.

In general, the quality and hedonic ratings considered with the increases in rancidification of fats, suggest that the cereal rations will probably remain acceptable for about 8 years in common storage. This will be in 1970 for most items, and sufficient controlled-storage samples remain for examination in 1969-70, so the storage study could about cover the useful life of the rations as presently stocked.

TABLE 17

HEDONIC RATINGS FOR CEREAL ITEMS STORED SIX YEARS

Condition	Items in Controlled Storage							
°F/% r.h.	CD1	CD8	CD2	CD7	CD9	CD10	std.dif. cans	Mean
Aroma:[a]								
Initial	5.58	6.28	6.80	6.54	5.30	5.60	.38	6.02
70/80	4.45	4.65	5.08	5.75	4.83	5.00	.28	4.96
70/57	5.20	4.65	5.75	5.65	4.75	5.03	.29	5.17
40/57	5.58	5.53	6.65	6.30	4.93	5.20	.55	5.70
0/amb	5.53	5.73	6.75	6.48	5.40	5.33	.37	5.87
std.dif.,cans	.54	.60	.31	.22	.19	.24	-	.39
sign.dif., 5%	.87	.83	.61	.44	.37	NS	.66[b]	.23
Mean	5.19	5.14	6.06	6.04	4.98	5.14	.28[c]	5.42
Flavor:[a]								
Initial	5.54	6.06	7.62	6.60	5.52	5.68	.37	6.17
70/80	.63	4.68	5.90	5.93	4.98	5.15	.26	5.21
70/57	5.13	4.80	6.30	5.60	4.98	4.73	.45	5.25
40/57	5.30	5.33	7.03	6.40	5.10	4.83	.48	5.66
0/amb	5.15	5.45	7.23	6.30	5.65	5.25	.42	5.84
std.dif.,cans	.32	.51	.38	.33	.56	.32	-	.41
sign.dif., 5%	.51	NS	.74	.48	NS	NS	.70[b]	.25
Mean	5.05	5.06	6.61	6.06	5.18	4.99	.31[c]	5.49
Palatability:[a]								
Initial	5.70	6.38	7.40	6.90	5.36	5.64	.28	6.23
70/80	5.05	5.03	5.85	6.28	5.25	4.98	.31	5.40
70/57	5.35	5.05	6.23	6.08	5.13	4.75	.28	5.43
40/57	5.50	5.40	6.80	6.58	5.15	4.88	.37	5.72
0/amb	5.35	5.45	6.93	6.45	5.70	5.13	.40	5.83
std.dif.,cans	.35	.50	.08	.13	.48	.29	-	.35
sign.dif., 5%	NS	NS	.16	.26	NS	NS	.58[b]	.21
Mean	5.31	5.23	6.45	6.34	5.31	4.93	.25[c]	5.60

(continued)

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TABLE 17 (continued)

Condition	Warehouse Samples Transferred to Controlled Storage									
°F/% r.h.	WC5	WC6	WB1	WB8	WB9	WB10	WB11	std.dif. cans	sign.dif. 5%	Mean
Aroma:[a]										
sample	5.44	5.08	6.31	6.76	6.34	5.68	5.80	.21	.37	5.92
70/57	5.08	4.68	6.18	6.25	5.38	4.80	5.23	.27	.46	5.37
Flavor:[a]										
sample	5.76	5.18	6.53	6.86	6.48	5.80	5.90	.27	.45	6.07
70/57	5.53	4.75	6.50	6.85	5.30	5.45	5.78	.37	.61	5.74
Palatability:[a]										
sample	5.68	5.28	6.57	6.80	6.66	5.80	5.88	.25	.41	6.10
70/57	6.05	4.95	6.83	6.95	6.15	5.78	5.95	.21	.35	6.09

[a]Leaking cans averaged 0.12 less than non-leakers at 70°F, 0.11 more than non-leakers at lower temperatures. Standard differences between duplicate cans among leakers and non-leakers, respectively, were 0.33 and 0.28 at 70°F, 0.49 and 0.36 at lower temperatures.
[b]Significant difference for items in rooms.
[c]Significant difference for item means.

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Indications are, however, that use of a better grade of fat than that of
the wafers and about half of the crackers and biscuits, with nitrogen
packing in non-leaking cans, could extend storage life of these types of
products by several more years at practical warehouse or shelter temperatures.

10. Correlations of Palatability Ratings With Other Measurements (Table 18)

The apparent correlations of palatability with various measurements
have depended in many instances on the temperature extremes used in the
study. Greatest changes have taken place at 100°F, least at 0°F, and
rancidity development has been characteristic of the high-temperature
samples, so other changes such as color fading, oxygen depletion, peroxide
and free fatty acid development, have occurred as the rations became stale
and rancid. With omission of the 100°F samples at 6 years, correlations
thus became less definite and more variable in sign, as seen in Table 18.

Correlations with Hunter L or lightness became increasingly negative,
and with Hunter "a" increasingly positive, through the first 4-5 years
when the predominant color change was fading at 100°F, but both decreased
as some degree of darkening began to affect the 100° and 70° samples. As
seen in the data, all were non-significant at 6 years except the total
cracker + biscuit coefficients, and these changed sign, indicating that
the higher L values and lower "a" values (i.e., the lighter-colored items)
now tend to receive higher scores. This shift also influenced a/b and
"b" correlations in corresponding manner.

Correlations with headspace oxygen became less definite with increase
in leaking cans and with omission of the low-oxygen cans from 100°F.
Those with free fatty acids were also sharply influenced by omitting the
highly-hydrolyzed 100°F fats, and correlations with peroxide values also
became less definite with the tendency for peroxidation to extend down
the temperature scale. Thus at this stage there appears to be no objective
measurement from which probable acceptance or shelf life could be
estimated with any great degree of reliability. At this stage of age of
the rations, however, it is quite probable that a high peroxide or free
fatty acid value would indicate the useful life of the ration is about
over, as the stability period of th fats seems to be about exhausted.

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TABLE 18

CORRELATIONS OF PALATABILITY RATINGS WITH OTHER MEASUREMENTS FOR CEREAL ITEMS STORED SIX YEARS
(simple correlation coefficient, r)

Palatability with:	Crackers			Biscuits			Crackers & Biscuits			Wafers		
	CD1	CD8	both	CD2	CD7	both	CD	Whse	total	CD9	CD10	both
Hunter L	-.071	-.564	-.320	+.071	+.087	+.043	+.580b	+.416	+.400b	-.227	-.054	+.493
a	-.098	+.466	+.258	-.033	+.574	-.035	-.467b	-.350	-.389b	+.311	+.200	-.142
b	+.488	+.773a	+.283	-.380	-.241	-.199	-.512b	-.631a	-.230	-.176	-.683	+.480
a/b	-.288	+.418	+.254	-.011	+.361	+.006	-.418a	-.047	-.219	+.121	+.358	-.344
Fracture Strength	+.173	+.798a	+.239	+.341	+.032	+.191	-.113	+.419	-.016	-.134	-.726a	+.369
Moisture Content	+.417	-.074	+.147	+.649	+.084	+.456	-.326	-.455	-.372a	-.314	-.441	-.122
Residual Oxygen	-.086	+.493	+.265	+.882b	+.812a	+.709b	+.606b	+.506	+.570b	+.642	+.550	+.499a
Peroxide Values	-.200	-.685	-.371	-.776a	-.737a	-.638b	-.312	-.861b	-.375a	-.330	-.314	+.080
Free Fatty Acids	+.380	-.595	-.279	-.904b	+.387	-.295	-.193	+.061	-.058	-.399	-.615	+.156
Sensory Scores:												
Appearance & Color	-.435	-.335	-/102	-.230	+.045	-.028	+.343b	+.275	+.320b	+.284	+.128	+.139
Texture	+.518	+.597	+.528a	+.858b	+.552	+.475	+.750b	+.808b	+.769b	+.336	+.410	+.583a
Aroma	+.212	+.620	+.452	+.949b	+.582	+.846b	+.283	+.451	+.241	+.516	+.736a	-.066
Flavor	+.572	+.677	+.642b	+.902b	+.622	+.751b	+.312	+.294	+.233	+.755a	+.727a	+.643b

a Significant at the 5% level of probability.
b Significant at the 1% level of probability.

B. The Carbohydrate Supplements

The carbohydrate supplements consisted of two flavors of hard candy, lemon and cherry, mixed in equal parts in each can. The two types were examined separately. Data and discussions are based on items and cans, type variations being noted only where distinct differences were observed. These included the data for Hunter Color and for the correlations among palatability ratings and other measurements.

The candies were packed in bulk in the cans, average 34.7 lbs. per can, with no lining or stuffing material. One banded packet of 20 kraft bags was included in each can, lying on the top of the candy. The bags were made as pouches by folding a 10½-inch x 3½-inch strip of kraft at 5 inches (leaving a ½-inch lip at the top) and sealing up the two sides with ½-inch seams, thus providing 3-inch by 5-inch internal dimensions.

1. Condition of Candy Bags (Table 19)

Measurements of length of top lip and internal size of bags were discontinued after the initial and first two storage examinations. Bags per can, width of side seams, and seam tests were determined on all examinations.

Bags per can. Counts of usable bags per can (some bags had holes, some were sealed only on one side) at 5 years, and cumulative counts for all cans examined through 5 years, were as follows:

	at 5 years bags per can	All cans examined through 5 years Range	Mean
CD11	20	21-16, 1 w/none	19.67
CD12	20.5	21-11, 1 w/none	19.35
CD13-14	20.38	21-19	20.03
All	20.29	21-11, 2 w/none	19.69

Width of side seams. Normal width of side seams is 04 (4/16 inch). Widths of seams on bags examined at 5 years, and on all bags examined through 5 years, were as follows:

	CD11	CD12	CD13-14	All
at 5 years				
no. of seams	320	328	326	974
range of widths	03-06	04-07	04	04-04
mean width	04.43	04.44	04.00	04.29
through 5 years				
no. of seams	3344	3372	3406	10122
range of widths	01-07	00-12	02-13	00-13
mean width	04.34	04.50[a]	05.02	04.62[a]

(cont)

TABLE 19

RESULTS OF SEAM TEST ON KRAFT BAGS STORED FIVE YEARS IN CARBOHYDRATE SUPPLEMENT CANS

Partial Separation, percentage of seams:

Condition °F/% r.h.	CD11		CD12		CD14	Total		std.dif.,cans		Mean, inches[a]	
	6-48 mo.	60 mo.	6-48 mo.	60 mo.	60 mo.	6-48 mo.	60 mo.	6-48 mo.	60 mo.	0-48 mo.	60 mo.
Initial	4.04%		2.05%		.00	2.03%		3.82%		.063	-
70/80	2.5	.0	1.5	.0	.0	2.00	.00	3.99	-	.087	.000
70/57	3.8	7.5	.8	1.2	.0	2.30	2.87	4.03	8.77	.063	.071
40/57	.6	.0	.0	.0	.0	.33	.00	2.17	-	.063	.000
0/amb	2.7	.0	1.1	.0	.0	1.90	.00	2.05	-	.063	.000
std.dif.,cans	3.57	7.50	2.80	1.19	-	3.21	4.39	1.87[b]	6.76[b]		
sign.dif., 5%	2.13	NS	NS	NS	-	1.32	NS	.94[c]	NS[c]		
Mean, percent	2.41	1.88	.87	.30	.00	1.64	.72	-	-		
Mean, inches[a]	.071	.073	.066	.063	.00	.070	.071				

Complete Separation, percentage of seams:

Condition °F/% r.h.	CD11		CD12		CD14	Total		std.dif.,cans		Mean, inches[a]	
	6-48 mo.	60 mo.	6-48 mo.	60 mo.	60 mo.	6-48 mo.	60 mo.	6-48 mo.	60 mo.	0-48 mo.	60 mo.
Initial	.00		.00		.00	.00		-			
70/80	.0	.0	1.3	.0	.0	.67	.00	5.25	-		
70/57	.0	.0	.0	.0	1.2	.00	.41	-	1.45		
40/57	.0	.0	.0	.0	.0	.00	.00	-	-		
0/amb	.0	.0	.4	.0	1.2	.21	.41	1.70	1.38		
std.dif.,cans	-	-	3.91	-	1.73	2.76	1.00	NS[b]	NS[b]		
sign.dif., 5%	-	-	NS	-	NS	NS	NS	NS[c]	NS[c]		
Mean	.00	.00	.43	.00	.61	.22	.21				

[a] Includes only seams which partially separated, not total seams.
[b] Significant difference for items in rooms.
[c] Significant difference for item means.

	CD11	CD12	CD13-14	All
total less than 04:	%	%	%	%
03	3.74	2.31	0.26	2.09
02	4.96	0.50	0.65	2.03
01	0.60	1.57	0.00	0.72
00	0.00	1.13	0.00	0.38
All	9.30	5.51	0.91	5.22

[a]38 missing seams (00) not included.

Seam Test. The seam test was a measure of linear separation of seams on a 1-inch cross section of bag when subjected to a steady 1-lb. pull for 5 minutes at 73°F/50% r.h. Data showing percentages of seams which partially separated, mean linear separation of these seams in inches, and percentages of seams which separated completely, for tests performed through 4 years and at 5 years, are listed in Table 19.

Although more partial separation was observed during the first two years, and more complete separation during the last three, it seems questionable whether there is any definite trend for changes in the bag seams. There were some differences among items, as seen in the data of Table 19; the greatest difference was between bags of CD13 (not sampled at 5 years) and those of the other items. Through 4 years, CD13 averaged about 5.4% partial separation and 10.0% complete separation, as compared to 4.7% and 0.1% for CD11 and 1.5% and 0.3% for CD12, respectively. Also, CD13 averaged higher at 40° and 0°F, whereas CD11 and CD12 had more separation at 100°F.

Total defective seams for the four items, as percentages of all seams examined, were as follows:

	CD11	CD12	CD13	CD14
first 4 years	4.73	1.83	14.84	-
5 years	1.88	0.30	-	0.61
total	4.46	1.68	-	-

Thus there is no indication that seam defects are increasing with storage; both CD11 and CD12 had highest percentage defectives at 6 and 24 months (averaging 7.9% for CD11, 2.7% for CD12), lowest at 12 and 60 months (1.2% and 0.7%), while CD13 averaged highest (20.8%) at 12 and 36 months, lowest (10.9%) at 6 and 48 months.

2. Condition of Candy (Table 20)

Characteristics of the candies which were considered not likely to be affected by storage were not determined after the first year. These were:

	CD11	CD12	CD13	CD14	Mean
Product weight lbs.	34.2	35.8	34.0	33.9	34.7
Piece count per lb.	120	89	88	107	99
Count % per can, lemon	48.3	48.3	49.2	46.8	48.6
cherry	51.7	51.7	50.8	53.2	51.4
Unsanded, count %	.08	.21	.01	.11	.10
Off-color, count %	.02	.01	.06	.06	.03
Off-shape, count %	5.2	1.1	2.9	2.0	3.1

Characteristics which could be influenced by storage and handling were determined at every examination. Data on these for the 5-year inspections are shown in Table 20.

Chipped Pieces. These were defined as pieces from which bits of surface or corners were chipped off, but which remained at least 75% intact. The general trend for increased chipping continued at the fifth year. CD11, averaging 0.9% increase per year from 1-4 years, was 1.1% higher than at 4 years; CD12, averaging 2.2% annual increase, was up 1.5%. CD14 was 1.6% above initial, as seen in Table 20.

As on previous examinations, there was no indication of a temperature effect, although it is possible that the apparent "aging" effect is at least partially a result of temperature variations within the storage rooms. Handling of cases undoubtedly increases chipping, but cases examined at 5 years had not been moved since 1966, so some factor other than handling is apparently involved in the more or less progressive increases.

There was, as usual, no consistent difference between lemon and cherry types in CD11; CD14 also averaged within 0.06% for the two flavors. CD12, however, averaged 0.87 ± .56% more chipping in lemon in 7 of 8 cans examined, although this item has exhibited no long-term trend in this direction. As mentioned in the previous report (Tech. Rpt. 156-V1-GES, June 1968), CD13 through 4 years averaged 7.4% chipped cherry type, 5.8% chipped lemon type, cherry being higher in 68% of all cans examined.

Broken Pieces. These were defined as anything riding an 8-mesh screen which was less than 75% of a whole piece. They were calculated, however, as count % whole pieces in excess of amounts required to restore chipped pieces to normal weight. Thus the total count % of broken pieces and bits was count % chipped X % weight reduction of chipped (footnote[a], Table 20) + count % broken pieces.

CD11 was again low, as it was at 4 years; this item averaged about 1.0% excess broken bits through 3 years. The difference could have resulted from the fact that the 4 and 5 year samples came from locations in the stacks which had not been shifted frequently, as had samples taken through the third year. CD12 and CD14 were apparently

normal for these items. CD12 apparently was chipped before packing in the cans, so that it has never averaged enough loose chips to restore chipped pieces to full weight.

Temperature differences remained variable, with no noticable trends. Average differences between types were small, lemon averaging 0.13 ± .04% higher than cherry in CD11 and CD14, 0.10% below cherry in CD12. The latter averaged 0.29% deficit in lemon chips, 0.05% deficit in cherry through 4 years, so the 5-year results apparently followed no previously established trend very closely.

Pieces Stuck Together. The counts for pieces of candy stuck together were about "average" for all items and conditions at 5 years, with the exception of one can of CD11 at 70°F/80% r.h. This can had a large clump, weighing 10 lbs 2 oz. containing an estimated 1212 pieces of candy firmly stuck together. These were about equally divided between lemon and cherry. Item CD11 has had one other can, at 100°/80%, in which a similar clump had apparently started to form, but was only loosely stuck together when examined. In addition, there have been three firmly-bound clumps of 39 pieces (70°/57% at 12 months), 42 pieces (100°/80% at 18 months), and 42 pieces (100°/80% at 48 months), and several involving 10-20 pieces. The moisture content in this item has been quite variable, and clumps apparently tend to form as a result of surface exchanges, particularly in leaking cans.

In addition to the large clump of CD11 at 70°/80%, distribution of clumping at 5 years was as follows:

pieces per clump	number of clumps			
	CD11	CD12	CD14	All
2	162	8	20	190
3	13	2	3	18
4	7	-	-	7
5,6,10,14	1 each	-	-	1 each

There was no consistent association with flavor type, or with storage condition except in CD11, in which the 0°/ambient ("wet") room also had more clumping than did either of the 57% r.h. conditions.

Material Passing 8-mesh Screen. As usual, sanding sugar and bits of candy passing the 8-mesh screen apparently varied only with cans and items. CD11 was below previous average (3.10%), CD12 slightly below (0.59%); CD14 was above initial (0.20%), which is the only previous data for this item. As seen in Table 20, can differences (largely CD11) were much larger in the "wet" rooms, probably associated with differences in current or former sealing of seams.

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TABLE 20

PHYSICAL CONDITION OF CARBOHYDRATE SUPPLEMENT STORED FIVE YEARS

Chipped Pieces[a], percent by count:

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
0-4 yrs:	3.7	14.5	(1.4)[f]	3.73	6.57[f]
70/80	5.9	15.7	2.8	3.26	8.12
70/57	6.4	24.6	2.9	2.52	11.31
40/57	4.8	21.6	3.4	2.10	9.93
0/amb	6.6	16.5	3.2	.78	8.74
std.dif.,cans	2.89[a]	2.74	.75	--	2.34
sign.dif., 5%	NS	2.69	NS	1.95[d]	1.05
Mean	5.92	19.58	3.08	.91[e]	9.53

Pieces Broken Up[b], percent by count:

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
0-4 yrs:	1.07	-.07	(.10)[f]	.79	.37[f]
70/80	.10	-.80	.13	.44	-.19
70/57	.02	-.19	.17	.26	.00
40/57	.16	-.41	.17	.65	-.03
0/amb	.34	.23	.17	.41	.25
std.dif.,cans	.76	.19	.17	--	.46
sign.dif., 5%	NS	.19	NS	.37[d]	.21
Mean	.15	-.29	.16	.20[e]	.01

Pieces Stuck Together, percent by count:

	CD11	CD12	CD14	std.dif. cans	Mean
0-4 yrs:	1.68	.08	(.11)[f]	.95	.52[f]
70/80	16.34	.03	.14	17.23	5.50
70/57	1.03	.10	.19	.56	.44
40/57	.71	.03	.28	.17	.34
0/amb	1.78	.19	.09	.65	.68
std.dif.,cans	14.94	.22	.17	--	8.63
sign.dif., 5%	NS	NS	NS	4.78[d]	3.84
Mean	5.02	.09	.17	2.23[e]	1.74

Material Passing 8-mesh[c], percent by wt:

	CD11	CD12	CD14	std.dif. cans	Mean
0-4 yrs:	3.1	.6	(.2)[f]	1.49	1.27[f]
70/80	2.3	.6	.7	1.08	1.21
70/57	2.0	.3	.7	.10	.99
40/57	2.6	.6	.8	.32	1.32
0/amb	4.0	.4	.6	2.78	1.66
std.dif.,cans	2.59	.15	.04	--	1.50
sign.dif., 5%	NS	.21	.07	2.42[d]	NS
Mean	2.73	.46	.70	1.19[e]	1.29

[a] Pieces with not more than 25% broken off; reductions from normal weight for the three items averaged 29.0, 3.4, and 7.3%, respectively.
[b] Estimated as count in excess of amounts of chips required to restore chipped pieces to normal weight; negative values indicate chips discarded from chipped pieces before packing in the can.
[c] Most of this material was sending sugar.
[d] Significant difference for items in rooms.
[e] Significant difference for item means.
[f] Initial value only for CD14.

3. Appearance and Color (Table 25)

Sensory scores for appearance and color of the carbohydrate
supplements were obtained from the five judges of the technical panel
in the same manner as that described above for the cereal items. The
two attributes were scored very nearly the same (correlation +.882), so
are listed as means for appearance-color in Table 25. Although
differences were not significant, samples of CD12 and CD14 from lower
temperatures were scored slightly lower because of a somewhat "duller"
appearance, particularly in the cherry type candy.

As seen in Table 25, all samples were scored lower than initial,
by averages of 0.90 at 70°F and 1.10 at lower temperatures. CD12
averaged 0.65 below, the other two items 1.15 below. Initials were
relatively high, however; the 5-year scores averaged slightly above
those at 4 years, and only 0.20 below the second and third year scores,
for items CD11 and CD12. Thus the appearance of the supplements has
actually changed very little except at 100°F, the candies at other
temperatures having merely lost some of the original "brightness" which
is typical of this type of product.

4. Hunter Color Values (Tables 21 and 22)

Color values were determined on duplicate samples of 4-8 mesh bits
of candy, cracked by hand to prevent "dusting" of surfaces. The Hunter
Color Difference meter was set with NBS Maize (L = 73.8, a = 1.4, b =
31.4) for lemon candy, NBS Kitchen Red (L = 28.7, a = 49.5, b = 18.1)
for cherry candy.

Hunter L Values. As on previous examinations, L or "lightness"
values were characterized more by can variance and variance among individual
pieces of candy than by any other factor. The lemon type of item CD14
(Table 21) was very nearly the same in L value as was CD13 at 36 and
48 months, however, so some idea of trends as noted by taste panels may
be obtained by comparisons of 5-year values with those of 3 and 4 years.
In such comparison, CD11 and CD14 decreased 1.05 ± 1.45, CD12 decreased
2.35 ± .70 units at 5 years. These decreases averaged 1.55 ± 1.60 at
70° and 0°F, 1.20 ± .20 at 40°F, thus corresponding reasonably well with
the moderate "dulling" of color noted by the panel judges. The greater
decrease in CD12 may have been associated with the "powdered" sugar with
which this item was sanded--the humidity of the work room was about 5%
higher than usual when the samples were cracked and screened for color
readings, and the fine sugar coating of CD12 had some tendency to adhere
to the fresh surfaces during screening.

The cherry type of CD14 (Table 22) averaged about 3.0 units lower
in L value than CD13, so period comparisons for this type were restricted
to CD11 and CD12. These averaged about the same as at 3 and 4 years,
± 1.50, being, however, 1.05 ± .05 higher at 70°/80%, 0.85 ± .50 higher
at 40°/57%, about the same ± 1.40 at 0°F, but 2.20 ± .45 lower at 70°/57%.
CD14 averaged 31.9 units at 70°/80%, 28.1 ± .5 at the other conditions.

Thus some indication of the slight "dulling" at lower temperatures, and lower humidities in the cherry type, is seen even with the rather extreme variations in samples.

Hunter "a" Values. As with L value, the "a" or red-green component of CD14 was apparently the same as that of CD13 lemon, allowing period comparisons, but different from CD13 in the cherry type. CD11 and CD13 lemon averaged 1.0 ± 1.4 lower than at 3 and 4 years, but CD12 lemon was 3.3 ± 1.4 lower. CD12 was actually pale yellow-pink instead of yellow-green, and there was no indication that the paler samples at 5 years were associated with storage--as seen in Table 21, samples 70°/80% and 40°/57% averaged 3.4 units lower than the other two, and these were largely responsible for the decrease in "a" reading. The same could have been the case with CD11 although the panel judges noted dullness of color (slight increases in green effect may appear as dullness in the near-zero "a" range) in the samples from high humidity conditions.

The "a" values of the cherry type, Table 22, could in each item have represented storage differences or merely sample variations, as the latter have been great enough to prevent estimates of any pattern except the color degradation formerly seen at 100°F. The lower values for CD11 at 70°F could have been due to slight fading, but these averaged 2.75 units higher than at 3 and 4 years. The 70°/80% and 0°/amb. samples of CD12 could have been high humidity effect, but they were not lower than at 3 years. CD14 had lower values at 40° and 0°F, with no precedent for this type of temperature effect--it seems quite probable that differences in red color of the cherry type samples were simply product variations.

Hunter "b" Values. The "b" unit of the color meter was the defective part which was repaired during the fifth year, so there seems little point in comparing the 5-year results with those of 3 and 4 years. The dulling noted in the lower-temperature lemon samples is easily seen in the "b" values of Table 21, however, as the 0°F value of CD11 and both the 40° and 0° values of CD12 and CD13 are lower. As noted for the "a" values of the cherry type, the "b" readings (Table 22) probably represent sample variations, as there is apparently no definite temperature pattern.

Hunter a/b Ratios. As seen in the tables, the a/b ratios are apparently not associated with storage differences. The ratios for lemon candy do indicate the predominant appearance of the items--pale green-yellow for CD11 and CD13, pink-yellow for CD12. The cherry types can only be described in terms of all color characteristics--CD11 a moderate (L = 30.6) purple-red ("chroma" 12.6, "hue" 3.0), CD13 similar but having more intensity (L = 29.0, chroma 18.6, hue 4.3), while CD12 is a brighter, "redder" item (L = 43.5, chroma 19.7, hue 1.8) lacking the purple overtone. These are, however, manufacturers' variations--apparently the 100°F temperature has been the only significant storage influence on the color of the supplements.

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TABLE 21

HUNTER COLOR VALUES OF LEMON TYPE CARBOHYDRATE SUPPLEMENT STORED FIVE YEARS

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean	CD11	CD12	CD14	std.dif. cans	Mean
	Hunter L:					Hunter "b":				
70/80	51.0	49.8	54.4	2.17	51.73	27.3	28.2	28.7	2.25	28.03
70/57	50.6	52.3	57.7	1.15	53.53	26.6	26.6	28.6	3.52	27.28
40/57	53.2	52.0	53.4	1.97	52.87	28.5	25.5	27.5	2.89	27.16
0/amb	51.5	50.6	52.5	1.85	51.52	26.6	24.7	26.6	.92	25.95
std.dif.,cans	2.18	1.66	1.58	-	1.83	2.11	1.85	3.48	-	2.58
sign.dif., 5%	NS	NS	1.30	2.86[a]	1.15	NS	NS	NS	NS[a]	NS
Mean	51.59	51.17	54.48	1.41[b]	52.41	27.27	26.21	27.84	NS[b]	27.10
	Hunter "a":					Hunter a/b:				
70/80	-3.2	4.1	-4.6	1.70	-1.20	-.116	.147	-.159	.071	-.043
70/57	-1.5	7.1	-4.6	.92	0.33	-.057	.267	-.161	.025	.012
40/57	-1.4	3.3	-4.7	1.87	-0.92	-.048	.130	-.170	.063	-.034
0/amb	-2.4	7.1	-4.9	1.44	-0.05	-.090	.289	-.183	.049	-.002
std.dif.,cans	1.74	.70	1.85	-	1.52	.068	.030	.059	-	.055
sign.dif., 5%	NS	1.38	NS	2.48[a]	.96	NS	.059	NS	.084[a]	.035
Mean	-2.12	5.41	-4.68	1.18[b]	-0.46	-.078	.207	-.168	.042[b]	-.017

[a] significant difference for items in rooms.
[b] significant difference for item means.

TABLE 22

HUNTER COLOR VALUES OF CHERRY TYPE CARBOHYDRATE SUPPLEMENT STORED FIVE YEARS

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Hunter L:					
70/80	31.5	43.3	31.9	2.50	35.53
70/57	30.4	42.3	28.7	2.71	33.77
40/57	31.4	43.8	27.9	1.81	34.33
0/amb	29.4	44.6	27.6	1.12	33.87
std.dif.,cans	2.22	2.5?	1.56	-	2.13
sign.dif., 5%	NS	NS	2.49	3.43[a]	1.54
Mean	30.64	43.48	29.00	1.64[b]	34.37
Hunter "a":					
70/80	9.3	15.0	21.6	.47	15.29
70/57	10.0	18.7	19.0	.67	15.89
40/57	16.4	18.2	15.8	3.19	16.79
0/amb	12.2	16.6	16.7	3.81	15.15
std.dif.,cans	2.33	2.39	2.81	-	2.52
sign.dif., 5%	4.58	NS	3.90	4.16	NS
Mean	11.98	17.0?	18.27	1.94	15.78

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Hunter "b":					
70/80	3.1	9.9	4.5	.52	5.83
70/57	3.6	10.4	4.9	1.28	6.28
40/57	4.7	9.3	3.7	.61	5.86
0/amb	4.5	9.3	4.0	1.01	5.93
std.dif.,cans	.61	1.37	.48	-	.91
sign.dif., 5%	.85	NS	.67	1.50[a]	NS
Mean	3.97	9.71	4.24	.70[b]	5.97
Hunter a/b:					
70/80	2.98	1.52	4.79	.38	2.63
70/57	2.78	1.79	3.92	.36	2.53
40/57	3.50	1.96	4.34	.49	2.87
0/amb	2.73	1.77	4.19	.22	2.56
std.dif.,cans	.39	.22	.51	-	.39
sign.dif., 5%	.62	NS	NS	.61[a]	.21
Mean	3.02	1.76	4.30	.30[b]	2.64

[a] Significant difference for items in rooms.
[b] Significant difference for item means.

5. Moisture Content (Table 23)

Moisture was determined as loss of weight on heating 20-mesh samples 24 hours at 65°-70°C with pressure about 30mm Hg.

Although the data of Table 23 indicate significant differences among storage conditions for moisture content of CD11 and CD14, with the 40°/57% condition averaging higher than the others for mean moisture, it is probable that the differences resulted from can or case-lot variance. There have been other significant differences among conditions over the five years of the study, but they have been quite inconsistent from period to period. The 40°/57% condition has averaged 1.71% overall, with 1.63% at 70°, 1.61% at 0°, and 1.57% at 100°, but each condition has varied from highest to lowest at various periods.

A general summary for levels and variations in moisture during the study is as follows (with CD14 sampled only initially and at 5 years):

	lemon %	cherry %	cans std.dev. ±	rooms std.dev. ±	periods std.dev. ±
CD11	1.69	1.65	.25	.34	.28
CD12	1.51	1.51	.06	.08	.13
CD13	1.75	1.62	.10	.08	.17
CD14	2.13	2.15	.08	.06	-

There has been no significant difference between leakers and non-leakers, and as seen, the variance has been largely in CD11, with a small but fairly consistent type difference in CD13. Apparently formulation and cooking have been the determining factors in moisture content.

6. pH Values (Table 23)

pH values were determined with the customary glass-electrode pH electrometer, using 1 ÷ 1 solutions of candy prepared with demineralized water. Although values through 4 years appeared to be following a downward trend, the 5-year values shown in Table 23 for CD11 and CD12 are fairly close to the 2-4 year averages for 70°F and below (6.07 for CD11, 6.57 for CD12). By conditions, differences between 5 and 2-4 years averaged -.23 ÷ .36 at 70°/80%, -.01 ÷ .21 at 70°/57%, and +.11 ÷ .29 at 40° and 0°F. Thus fluctuation appears to be the chief characteristics of the 2-5 years data on pH. There was no indication of consistent difference between 100° and 70°F through 4 years, but the 5-year values suggest that there may be a slight reduction at 70° as compared with lower temperatures.

There have been no significant differences in pH of lemon and cherry types of candy, even though the cherry type of CD11 averaged .22 higher than the lemon at 5 years. pH was negatively correlated with moisture content in both lemon (-.701) and cherry (-.526) types as a whole, but no single-item correlation was as large. Thus there appears to be no temperature-moisture-pH relationship which might tend to increase hydrolysis of the sucrose content of the candies more than slightly.

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TABLE 23

MOISTURE CONTENT AND pH VALUES FOR CARBOHYDRATE
SUPPLEMENT STORED FIVE YEARS

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Moisture Content, percent:					
Initial	1.52	1.34	1.55	.21	1.47
70/80	2.03	1.69	2.21	.43	1.98
70/57	1.73	1.66	2.07	.08	1.82
40/57	2.49	1.65	2.17	.02	2.11
0/amb	1.60	1.66	2.12	.07	1.79
std.dif.,cans	.37	.05	.08	-	.22
sign.dif., 5%	.60	NS	.11	.23[a]	.20
Mean	1.96	1.67	2.14	.12[b]	1.92
pH Values:					
Initial	6.55	6.70	6.40	.10	6.55
70/80	6.07	6.29	5.95	.08	6.10
70/57	6.12	6.38	6.01	.05	6.17
40/57	6.23	6.55	6.04	.07	6.27
0/amb	6.23	6.62	6.03	.03	6.29
std.dif.,cans	.05	.07	.06	-	.06
sign.dif., 5%	.10	.14	NS	.09[a]	.06
Mean	6.16	6.46	6.01	.05[b]	6.21

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

7. Sugar Contents (Table 24)

Sugars were determined by the official Lane-Eynon general volumetric procedure, with acid inversion at 73°F (Association of Official Agricultural Chemists, Washington, D. C.). Reducing sugar titrations were corrected for sucrose effect as directed by Fitelson (J. Assoc. Off. Agr. Chem., 1932, p. 624). All results were calculated on a dry weight basis.

Reducing Sugars as Dextrose. While the dextrose values given in Table 24 average about 1.0% higher than previous means at 70° and 0°F, they were not above previous high values, and the 40°F values averaged about 1.0% below previous highs. There was nothing to indicate any definite storage effect in these temperature ranges, the 70° and 0° samples being closer together than to the 40° samples in both CD11 and CD12. The pattern in CD14 could indicate a small amount of hydrolysis in the 70°/80% sample (i.e., higher reducing sugar and moisture-content, lower pH and sucrose content) but differences observed were within the range of can variations, and the pattern was not observed in the other two items.

Sucrose. The averages for sucrose were about 1.5% above mean levels at 70° and 0°F, and 2.5% high at 40°F. The 70° and 0° values were not above previous highs, however, and the 40°F average was only 1.0% above, corresponding to the 1.0% reduction below previous high values for dextrose. These relationships suggest (a) that all of the sugars determined at 5 years were perhaps slightly higher than "average" as a result of variation in laboratory procedure, and (b) the 40°F sample of CD11 was simply lower in dextrose and higher in sucrose as a normal sample variation. There were only small differences in either dextrose or sucrose among storage conditions for CD12, and dextrose and sucrose were negatively correlated in CD11 and CD14, regardless of temperature, again suggesting sample differences as the primary source of variance. CD14 sucrose was lower by about the same amount as the increase in CD14 reducing sugar, in accord with the suggestion of possible hydrolysis in this sample.

Total Sugars. The values for total sugars of Table 24 are, of course, the sums of values for dextrose and sucrose. Comparison of standard differences listed for duplicate cans will indicate that variations in the two types of sugars tended to be somewhat "complementary" (i.e., higher dextrose matched with lower sucrose) in CD11, but less so in CD12, in which the variations in sucrose appeared to be predominant. Room differences for CD12 averaged a uniform 0.3% for dextrose, sucrose and total sugars; and for CD11 room differences averaged 1.1% for dextrose and total sugars, 2.2% for sucrose. Thus sucrose variation among cans and samples appears to be the predominant source of variance in these items.

The pattern for CD14, however, is definitely a complementary or "inversion" type, with can differences of .69% and .77% for reducing sugars and sucrose but only .17% for total sugars. Room differences for

TABLE 24

SUGAR CONTENT OF CARBOHYDRATE SUPPLEMENT STORED FIVE YEARS

Dextrose, percent:

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Initial	19.4	16.3	17.9	.46	17.84
70/80	19.9	16.8	18.7	.38	18.50
70/57	20.3	16.7	18.1	.77	18.35
40/57	18.7	16.5	18.0	.99	17.72
0/amb	20.2	16.8	17.6	.89	18.22
std.dif.,cans	1.17	.23	.69	-	.79
sign.dif., 5%	NS	NS	NS	1.14[a]	.64
Mean	19.78	16.70	18.11	.54[b]	18.20

Sucrose, percent:

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Initial	62.8	65.1	64.1	.75	64.03
70/80	64.3	66.5	63.7	.52	64.83
70/57	63.3	66.6	64.3	.97	64.71
40/57	66.7	66.4	64.4	1.63	65.84
0/amb	63.9	66.2	64.6	.60	64.89
std.dif.,cans	1.48	.62	.77	-	1.03
sign.dif., 5%	2.36	NS	NS	1.39[a]	.33
Mean	64.54	66.43	64.24	.66[b]	65.07

Total Sugar, percent:

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Initial	82.2	81.4	82.0	.97	81.87
70/80	84.2	83.3	82.5	.51	83.33
70/57	83.6	83.2	82.3	.45	83.06
40/57	85.4	82.9	82.4	.76	83.56
0/amb	84.1	83.0	82.2	.73	83.11
std.dif.,cans	.85	.65	.17	-	.63
sign.dif., 5%	1.36	NS	NS	.93[a]	.47
Mean	84.32	83.13	82.35	.43[b]	83.26

Dextrose/Sucrose ratio:

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Initial	.309	.250	.273	.008	.279
70/80	.310	.253	.294	.007	.285
70/57	.322	.250	.231	.017	.284
40/57	.280	.249	.279	.022	.269
0/amb	.316	.254	.272	.016	.281
std.dif.,cans	.024	.004	.015	-	.016
sign.dif., 5%	NS	NS	NS	.024[a]	.014
Mean	.307	.252	.282	.011[b]	.280

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

CD14 were .72% for reducing sugars, .54% for sucrose, .19% for total sugars. Thus, while no definite temperature effect is statistically demonstrated (can and room variances about equal), the predominant difference appears to be the amount of reducing sugar vs sucrose included in a relatively constant content of total sugars. The higher moisture and lower pH of the 70°/80% candy of CD14 could, therefore, be associated with increased inversion in this sample.

Dextrose/Sucrose. The ratios seen in Table 24 follow the patterns discussed above, indicating more or less heterogeneous contents of dextrose and sucrose in CD11, uniform contents in CD12, and a possible inversion pattern (associated with temperature, pH and moisture) in CD14.

The general appearance and other sensory characteristics of the candies also suggested that no significant patterns of sugar changes had been established in the samples stored at 70°F and below. Previous observations of samples stored at 100° definitely suggested some degree of inversion and quite a significant amount of change in crystal structure, with possible involvement of breakdown reactions at this elevated temperature. No such changes were observed in the current examinations of candies stored at 70°, 40°, or 0°F.

8. Sensory Scores: Texture, Aroma and Flavor (Table 25)

Scores were assigned by the five-member technical panel in the manner described for cereal items (Section III.A.3.).

Texture. As seen in Table 25, texture scores for the hard candies ranged 7.5-7.8, with no significant differences for any factor. The scores averaged .71 ± .18 below initial, .59 ± .17 below previous highs for periodic examinations, and .03 ± .13 below previous averages for each of the four storage conditions. In short, texture of the hard candies was scored 7.6 ± .1, the only significant variance being that among judges, ± .53.

The average at 100°F through 4 years was 7.5, so storage apparently has had practically no influence on texture except a mean decrease of about 0.7 scale point from initial scores. It seems doubtful if this decrease was actually associated with storage, the more likely reason being that the judges simply scored the new product somewhat higher than their real opinion of it for routine use--the candy is hard to chew, which must be done for texture evaluation.

Aroma. Table 25 shows the variations of aroma scores with time and temperature of storage. Values given average 1.00 ± .24 below initial at 70°F and 0.40 ± .32 below initial at lower temperatures, the chief reason for decreases being listed as loss of fresh aroma. Decreases from previous storage averages were 0.72 ± .39 at 70° and 0°F, 0.46 ± .32 at 40°F, with average decrease from previous low scores of 0.05 ± .39 for all conditions. As the 4-year average at 100°F was 4.57 ± .44, with "off"

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TABLE 25

APPEARANCE-COLOR, AROMA, TEXTURE, FLAVOR SCORES OF CARBOHYDRATE SUPPLEMENT STORED FIVE YEARS
(scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Appearance-Color					Texture				
	CD11	CD12	CD14	std.dif. cans	Mean	CD11	CD12	CD14	std.dif. cans	Mean
Initial	8.35	8.25	8.20	.27	8.27	8.2	8.6	8.2	.16	8.33
70/80	7.10	7.75	7.30	.50	7.38	7.7	7.6	7.6	.12	7.63
70/57	7.10	7.75	7.15	.25	7.33	7.7	7.7	7.5	.20	7.63
40/57	7.30	7.40	7.05	.27	7.25	7.8	7.6	7.6	.00	7.67
0/amb	7.00	7.45	6.85	.34	7.10	7.6	7.6	7.5	.12	7.57
std.dif.,cans	.29	.28	.46	-	.35	.15	.10	.15	-	.13
sign.dif., 5%	NS	NS	NS	.57[a]	NS	NS	NS	NS	.21[a]	NS
mean	7.13	7.59	7.09	.27[b]	7.27	7.70	7.63	7.55	.10[b]	7.63

Condition °F/% r.h.	Aroma					Flavor				
	CD11	CD12	CD14	std.dif. cans	Mean	CD11	CD12	CD14	std.dif. cans	Mean
Initial	7.4	7.6	7.3	.31	7.42	7.9	7.3	7.6	.38	7.60
70/80	6.0	6.7	6.3	.37	6.33	7.1	6.4	6.5	.72	6.67
70/57	6.1	6.9	6.5	.39	6.50	7.1	7.4	6.7	.44	7.07
40/57	6.7	7.4	7.0	.35	7.03	7.0	7.3	7.2	.26	7.17
0/amb	6.5	7.7	6.8	.44	7.00	7.0	7.6	7.4	.52	7.33
std.dif.,cans	.34	.48	.32	-	.39	.55	.65	.25	-	.52
sign.dif., 5%	.55	.75	.50	.62[a]	.35	NS	1.03	.49	.82[a]	.46
Mean	6.33	7.18	6.65	.30[b]	6.72	7.05	7.18	6.95	NS[b]	7.06

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

or "terpene" aroma noted, a clearly defined difference in stability of aroma at 100°, 70°, and the lower temperatures is evident. Although judges did not agree very well (± .85) on extent of loss of aroma, there has been no significant development of off aroma at 70°F.

Flavor. Decreases from initial flavor scores averaged 0.93 ± .10 at 70°/80%, 0.48 ± .41 at 70°/57% and 40°/57%, and 0.27 ± .50 at 0°F. Off flavors were noted in the 70°/80% sample of CD12 and in both of the 70° samples of CD14. These were the first significant mention of off flavors at 70°F, at least of the "terpene" type of flavor which resulted in reduction of 100°F samples to a score of 5.22 ± .17 at 4 years. Scores in Table 25 averaged 0.25 ± .39 above previous lows and 0.31 ± .30 below previous averages for the four conditions shown, with a fairly large judge deviation (± 1.49) and a can difference of 0.52. Thus the general pattern appears to be one of variation among cans rather than damage from storage--70°F samples averaged 6.85, 40° and 0° samples 7.25, which are only about 0.10 less than the 3-4 year averages at these temperatures.

9. Hedonic Ratings: Aroma, Flavor and Palatability (Table 26)

The hedonic evaluations of the supplements were made in the manner described above (Section III.A.9.), several pieces of each of the two types of candy being presented as each coded sample.

Aroma. The aroma ratings given in Table 26 averaged 0.14 ± .24 less than initial but 0.21 ± .19 more than previous ratings at 70°F, with increase of 0.11 ± .24 above initial and 0.28 ± .15 above previous ratings at 40° and 0°F. Judge variance was ± 1.18, but comments indicated the disagreement involved estimates of the amount of aroma loss, with no mention of off or "terpene" aroma. When compared to the 1.08 ± .29 decrease in aroma in 4 years at 100°F, it is apparent that storage for 5 years at 70° and below has had relatively little effect on the aroma of the supplements.

Flavor. Flavor ratings averaged 0.79 ± .18 less than initial at 70°/80% and 0.58 ± .29 less at the other conditions. Slight "terpene" off flavor was noted in the 70°/80% sample of CD12, other decreases being predominantly for lack of fresh flavor. The 6.67 mean rating of the CD12 sample indicates that the "terpene" flavor was slight. 100°F samples averaged 1.35 ± .35 under initial at 4 years because of this off flavor, while the present sample was down only 0.57, or about 0.3 more than other 70°/80% samples were marked off for loss of flavor. In comparison with previous ratings, CD11 and CD12 averaged 0.06 ± .21 lower, but CD14 was 0.30 ± .15 above the average which had been established for CD13 through the first four years. Obviously, with ratings ranging 6.67-7.40, average 7.02, none of the samples were seriously affected by storage, although a judge variance of ± 1.19 indicated some disagreement as to how much flavor had been lost.

Palatability. The ratings given in Table 26 averaged 0.49 ± .12 below initial, with little difference among storage conditions. As the 4-year ratings for 100°F samples were 1.50 ± .21 below initial (candies

TABLE 26

HEDONIC RATINGS FOR CARBOHYDRATE SUPPLEMENTS STORED FIVE YEARS

Condition °F/% r.h.	CD11	CD12	CD14	std.dif. cans	Mean
Aroma:					
Initial	6.88	6.76	7.28	-	6.97
70/80	6.43	6.90	7.00	.22	6.78
70/57	6.50	6.85	7.32	.25	6.89
40/57	6.80	7.15	7.40	.09	7.12
0/amb	6.62	7.18	7.33	.15	7.04
std.dif.,cans	.16	.22	.17	-	.19
sign.dif., 5%	.25	NS	.33	.30[a]	.17
Mean	6.59	7.02	7.26	.15[b]	6.96
Flavor:					
Initial	7.76	7.24	7.97	-	7.66
70/80	6.77	6.67	7.13	.27	6.86
70/57	6.85	6.88	7.40	.32	7.04
40/57	6.85	7.00	7.40	.10	7.08
0/amb	6.78	7.10	7.40	.30	7.09
std.dif.,cans	.25	.30	.23	-	.26
sign.dif., 5%	NS	NS	NS	.42[a]	.22
Mean	6.81	6.91	7.33	.20[b]	7.02
Palatability:					
Initial	7.48	7.40	7.85	-	7.58
70/80	6.87	7.02	7.23	.08	7.05
70/57	6.82	7.02	7.47	.15	7.11
40/57	6.98	7.03	7.37	.05	7.13
0/amb	6.80	7.00	7.36	.22	7.08
std.dif.,cans	.05	.15	.19	-	.14
sign.dif., 5%	.09	NS	NS	.23[a]	NS
Mean	6.87	7.04	7.37	.11[b]	7.09

[a]Significant difference for items in rows.
[b]Significant difference for item means.

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were dropped at 100°F primarily because of degradation of color), storage at 70°F and below has had little adverse effect on acceptability of the supplements. The 5-year ratings for CD11 and CD12 were 0.0ⁿ ± .20 above previous levels, while CD14 averaged 0.45 ± .17 above the mean rating of CD13 through 4 years (initial ratings for CD14 were 0.18 ± .07 above those for CD13). Judge variance for palatability ratings was ± 1.10, indicating some difference in individual rating levels, as the standard difference of can means was only 0.14 and the total range of condition means only 0.22 within any single item.

In general, the hedonic ratings for carbohydrate supplements at 5 years indicate that this product will probably remain acceptable for several more years at moderate to low storage temperatures.

10. Correlations of Palatability Ratings and Other Measurements (Table 27)

With omission of the 100°F samples, thereby eliminating the primary source of storage differences as well as 1/3 of the degrees of freedom, it is not surprising that the number of statistically significant correlations among the 228 shown in Table 27 dropped from 72 at 4 years to 48 at 5 years.

As seen, there were indications of preference for the brighter samples of the lemon candy and the redder samples of the cherry type, for candies with higher moisture and sucrose, lower pH, dextrose and total sugars. But high moisture, lower pH, and lower dextrose would not normally be an expected combination, so the entire pattern probably was influenced mainly by the fact that low-temperature samples usually scored higher. In addition to being quite "scattered", there was a somewhat surprising lack of correlation between palatability ratings and sensory quality scores.

The general correlation of higher moisture with lower pH would be expected to result in higher dextrose and lower sucrose, yet these were both positive and negative among the various items with respect to moisture. Lower pH per se did seem to be associated with higher dextrose and lower sucrose, but the overall pattern was too inconsistent to support any definite conclusions.

SUMMARY AND CONCLUSIONS

Civil Defense shelter rations from four procurement lots of crackers, three of biscuits, two of wafers, and three of carbohydrate supplements were partially examined (cans, color, flavor, rancidity values) after storage for 67-70 months variously in six controlled conditions at 100°, 70°, 40° and 0°F. Based on these "preliminary" results, which confirmed results of the complete examinations which were made after five years, samples stored at 100°F were eliminated from further study and a full set of samples remaining at 70°F and below was reserved for examination after seven years of storage. Remaining available samples were then scheduled for examination after six years.

The sixth-year samples included two lots each of crackers, biscuits, and wafers from 70°F/30% r.h., 70°/57%, 40°/57%, and 0°/ambient r.h. in the storage study, and two samples of crackers and five of biscuits which had been held 2-3 years at 70°/57% after removal from various warehouses in a previous sampling sur   . Also included were two lots of carbohydrate supplement from the storage study and one lot which had been stored with the study items but not examined since initial. All supplement samples had been stored five year from March 1964.

Results of examinations of the V3c fiberboard cases, 2½-gallon and 5-gallon metal cans, ration packaging materials and candy bags, and of the individual cereal and supplement rations in two cans from each storage condition are given in detail. Brief comparisons with results of previous examinations are frequently included.

I. Fiberboard Cases

1. Bursting strength of fiberboard averaged 23 ± 18 psig below initial after 5-6 years at 70°F, but remained 40 ± 17 psig above initial after the same periods at 40° and 0°F. Decreases had averaged more than 150 psig after five years at 100°F.

2. Moisture content of the fiberboard averaged 10.9 ± .2% at 70°/80%, 7.6 ± .3% at 70°/57%, 8.9 ± .1% at 40°/57%, and 13.2 ± .7% at 0°/amb. Moisture was not significantly correlated with bursting strength.

3-4. General condition of cases remained satisfactory for continued storage.

II. Metal Cans

1. Residual oxygen in crackers and biscuits, for non-leaking and leaking cans, respectively, averaged 11.6 ± 2.1% and 15.4 ± 4.7% at 70°F, 15.6 ± 2.9% and 19.5 ± 2.5% at 40°F, and 19.6 ± .8% and 19.1 ± 2.4% at 0°F. Wafers, all non-leakers, averaged 1.8 ± 1.1%, 3.2 ± .8%, and 15.5 ± .7% at the three temperatures. Previous leaking of some "non-leaker" cracker and biscuit cans was suggested by relatively high values.

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TABLE 27

CORRELATIONS OF PALATABILITY RATINGS AND OTHER MEASUREMENTS
FOR CARBOHYDRATE SUPPLEMENT STORED FIVE YEARS
(simple correlation coefficient, r)

	Lemon Type				Cherry Type				Combined Products			
	CD11	CD12	CD14	All	CD11	CD12	CD14	All	CD11	CD12	CD14	All
Palatability with:												
Hunter L	+.414	+.288	+.092	+.605[b]	+.555	+.588	-.523	-.252				
a	+.001	+.333	+.489	-.332	+.661	-.322	-.064	+.602[b]				
b	+.542	-.176	-.355	+.131	+.265	+.279	+.217	-.102				
a/b	+.026	+.342	+.439	-.318	+.872[b]	-.541	-.302	+.576[b]				
Moisture	+.859[b]	+.462	-.112	+.257	+.937[b]	+.872[b]	-.226	+.558[b]	+.830[b]	+.644[b]	-.165	+.417[b]
pH	+.220	+.188	+.368	-.098	-.255	+.070	+.051	-.585[b]	+.065	+.102	+.115	-.358[a]
Dextrose	-.150	-.263	-.532	-.358	-.928[b]	-.197	-.151	-.385	-.504[a]	-.230	-.372	-.370[b]
Sucrose	+.359	+.157	+.512	-.087	+.914[b]	-.250	+.218	-.091	+.605[a]	-.024	+.365	-.089
Total Sugar	+.427	+.030	+.290	-.597[b]	+.693	-.327	+.342	-.708[b]	+.485	-.160	-.018	-.639[b]
Dextrose/Sucrose	-.218	-.334	-.549	-.293	-.934[b]	+.055	-.137	-.301	-.553[a]	-.138	-.369	-.297[a]
Sensory App - Color									+.593[a]	-.009	-.475	-.196
" Texture									+.621	-.666	+.207	-.479[a]
" Aroma									+.382	-.112	+.434	+.187
" Flavor									+.143	+.164	+.339	-.025
Moisture with:												
pH	-.031	-.651	-.090	-.701[b]	-.200	-.300	-.430	-.526[b]	-.287	-.302	-.386	-.601[b]
Dextrose	-.127	+.134	+.232	+.522[b]	-.964[b]	-.023	+.126	-.217	-.498[a]	+.114	+.174	+.143
Sucrose	+.287	-.767[a]	-.253	-.356	+.921[b]	-.205	+.025	+.127	+.595[a]	+.146	-.137	-.086
Total Sugar	+.335	+.782[a]	+.020	+.255	+.653	-.228	+.474	-.119	+.476	-.190	+.099	+.080
Dextrose/Sucrose	-.175	-.304	+.240	+.510[a]	-.960[b]	+.136	+.052	-.216	-.544[a]	-.013	-.153	+.129

(continued)

TABLE 27 (continued)

	Lemon Type				Cherry Type				Combined Products			
	CD11	CD12	CD14	All	CD11	CD12	CD14	All	CD11	CD12	CD14	All
pH with:												
Dextrose	-.284	-.104	-.013	-.674[b]	+.268	-.307	-.624	-.286	-.217	-.167	-.190	-.477[b]
Sucrose	+.515	-.695	+.336	+.653[b]	-.154	+.212	+.517	+.575[b]	-.202	-.030	+.131	+.599[b]
Total Sugar	+.544	-.701	+.662	-.098	+.056	+.142	-.006	+.482[a]	+.600[a]	-.092	+.480	+.165
Dextrose/ Sucrose	-.386	+.255	-.083	-.711[b]	+.251	-.311	-.593	-.350	-.226	-.101	-.243	-.518[b]

[a] Significant at the 5% level of probability.
[b] Significant at the 1% level of probability.

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2. All except one (95%) of the 2½-gallon cans examined were leakers. Four of the eight 5-gallon can items had no leakers with 17% leakers in one item, 33% in two, and 50% in one. All leaks were attributed to defective seams.

3. Coating defects as abrasion averaged 0.4 ± .2 (0-9 scale) on 2½-gallon cans; unevenness, abrasion, and loosening by corrosion on 5-gallon cans averaged 1.3 ± .5 at 70°/80%, 0.9 ± .3 at 70°/57% and 40°/57%, and 0.70 ± .3 at 0°F.

4. External corrosion averaged 1.7 ± .7 (0-9 scale) at 70°/80%. At 70°/57% and the lower temperatures, averages were 0.3 ± .2 for 2½-gallon cans and 0.8 ± .5 for 5-gallon cans. Internal corrosion averaged 0.7 ± .3 in 2½-gallon cans, with 1.0 ± .3 at 70°F and 0.8 ± .3 at 40° and 0°F in 5-gallon cans. Most corrosion was located where products touched can walls.

III. The Rations

A. Cereal Items.

1. Broken packages varied with quality of wrapper and type of pack; three warehouse items with heavy waxed paper had no broken packages, and the heavy paper of biscuit CD2 and moderately good wrappers of the compactly-packed wafers averaged only 1.4 ± 1.4% breakage. Three cracker or biscuit items with moderately heavy wrapping material averaged 9.5 ± 12.3%, about equally broken seals and torn corners but with 6.7% of the breakage from 0°F. Four cracker or biscuit items wrapped in fragile "glassine" averaged 56.1 ± 22.0%, 39.8% of which was torn packages from the 57% r.h. conditions.

2. Product breakage varied with type of product, packing, and with brittleness after baking in the crackers and biscuits. Four cracker or biscuit items averaged 9.8 ± 3.7%, 7.5% being score-line separations. One cracker and one biscuit item averaged 19.1 ± 6.7%, 11.0% being score-line. Cracker CD8 and the wafers averaged 26.2 ± 7.8%, the cracker being 21.2% unit breakage but wafers almost entirely crumbled edges. Three warehouse items averaged 34.3 ± 3.1% and one 49.5%, about equally score-line and unit breakage for the four items.

3. Appearance and color scores (10-1 scale) averaged within 0.3 ± .3 of previous scores, about 0.6 under initial, because of slight glazing of surfaces and very slight dulling or darkening. Storage differences were non-significant for these and for texture scores.

4. Hunter Color values indicated all rations had slightly more "glaze" on the surface than when initially examined. The darker items were still somewhat lighter (increased L value, decreased "a" value) than when baked, but all items had darkened slightly during the last two years of storage.

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5. Fracture strength ranged about 1000-2600 grams per unit by items, and was apparently related only to degree of baking and other item characteristics.

6. Moisture content ranged 1.6-3.4%, mean 2.6% in crackers and biscuits, and averaged 3.96 ± .15% in wafers. Moisture levels were apparently related only to item characteristics.

7. Peroxide values averaged 3.8 ± 1.4 m-eq. from 0°F, 8.6 ± 6.4 from 40°, and 15.8 ± 8.6 from 70° storage. Crackers averaged 15.7 ± 8.4, biscuits 12.5 ± 9.0, wafers 6.9 ± 5.9. Free fatty acids averaged 0.33 ± .11% from 70°F and 0.29 ± .11% from lower temperatures, item means ranging 0.17-0.46% as a result of varying stability of fats used in manufacture.

8. From initial mean of 6.7 ± .9, aroma and flavor scores by the technical panel dropped to 5.5 ± .6 at 70°F and 6.3 ± .6 at 40°, averaging 6.7 ± .5 at 0°F. Product averages of 6.0 for crackers and biscuits, 5.6 for wafers, have changed relatively little since the fourth year at 70° and below.

9. Hedonic ratings for aroma, flavor and palatability dropped from initial mean of 6.1 ± .7 to means of 5.4 ± .7 at 70°F and 5.8 ± .6 at lower temperatures. Aroma and flavor ratings averaged 5.1 ± .4 for crackers and wafers, 6.0 ± .6 for biscuits; palatability means were 5.2 ± .3 for crackers and wafers, 6.4 ± .4 for biscuits. From fourth-year ratings at 70°F crackers decreased about 0.5, biscuits and wafers averaged no change, while from ratings at lower temperatures crackers and wafers decreased about 0.2, biscuits gained 0.5.

10. Palatability ratings were correlated with residual oxygen and peroxide values in biscuits; other correlations were poor or nonsignificant.

B. Carbohydrate Supplements

1. Seams of candy bags averaged about 1.5% partial separation and 0.2% complete separation over 5 years, with no indication of increase at the fifth year.

2. Chipping of candy continued the ca 1.3% annual increase, mostly in one item. Additional breakage was negligible, loose sanding sugar and bits of candy averaged the usual 1.3%, and sticking together of pieces averaged the usual 0.5% excepting one can with a 10-lb clump.

3. Appearance-color scores averaged 1.0 below initial, but only 0.2 below the 2-4 year average; color is apparently stable at 70°F and below.

4. Hunter Color values were characterized mainly by can variations, although some slight "dulling" of color was indicated by reductions in L value.

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5. Moisture content ranged 1.6-2.5%, mean 1.9%, with no significant variance other than that associated with items and cans.

6. pH averaged 6.14 ± .16 at 70°F and 6.28 ± .23 at 40° and 0°F. One lower-moisture item (1.67%) averaged 6.46, two higher-moisture items (2.05%) averaged 6.08.

7. The item with moisture 1.67%, pH 6.46 averaged 16.7% dextrose, 66.4% sucrose, D/S ratio 0.252. The two items averaging 2.05% moisture, pH 6.08, averaged 18.9% dextrose, 64.4% sucrose, D/S ratio 0.294. There was, however, no indication of hydrolysis of sucrose associated with storage temperatures, and periodic variations have been too great to afford any definite association of hydrolysis with storage time.

8. Texture scores averaged 7.6 ± .1, 0.7 ± .3 below initial, with no variation associated with storage. Aroma scores averaged 6.4 ± .4 at 70°F and 7.0 ± .5 at lower temperatures, from initial 7.4 ± .2. Flavor scores averaged 6.9 ± .4 at 70° and 7.25 ± .22 at 40° and 0°F, from initial 7.6 ± .3. Reductions were attributed to slight loss of fresh aroma and flavor.

9. Hedonic ratings averaged 6.83 ± .31 at 70°F and 7.08 ± .28 at lower temperatures for aroma, 6.86 ± .20 at 70°F/80% r.h. and 7.07 ± .25 at other conditions for flavor, and 7.09 ± .22 at all conditions for palatability. Item variance was ± .24, decreases from initial averaged 0.28 ± .27, but 5-year ratings averaged 0.15 above the general average of the first 4 years. Storage at 70°F and below has apparently had little effect on the carbohydrate supplement.

10. Correlations of palatability ratings with other measurements were generally poor, offering no apparent method of estimating quality other than by sensory evaluation.

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13. ABSTRACT

Results are reported on the stability of 6 lots of fallout shelter cereal rations and 3 lots of carbohydrate supplement stored 6 and 5 years, respectively, at 70°F/80% r.h., 70°/57%, 40°/57%, and 0°/ambient r.h. Cereal rations include 2 lots each of survival crackers, biscuits, and bulgur wheat wafers. Samples of 7 items (2 crackers and 5 biscuits) held 2-3 years at 70°/57% after withdrawal from warehouse stocks were also examined, but samples of supplement and cereal rations held 5-6 years at 100°/80% and 100°/57% were omitted as unsuitable for further storage. Data include (1) bursting strength, moisture content, and general condition of V3c fiberboard cases, (2) residual oxygen, leaking and condition of seams, corrosion, and coating defects of 2½-gallon and 5-gallon metal cans, (3) breakage of package seals, seams or materials, and of product units, (4) fracture strength and rancidity values of cereal items, (5) pH and sugar contents of supplement items, and (6) moisture content, color, sensory quality, and hedonic ratings of all items.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Storage stability	8					
Cans	9					
Fiberboard	9					
Containers	9					
Food containers	9					
Rations	4		4			
Survival	4		4			
Civil Defense	4		4			
Shelters	4		4			
Acceptability			8			
Flavor			8,9			
Bakery Products			8,9			
Carbohydrate supplements			8,9			